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and of the

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VOLUME XVI, 1915-16

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INTRODUCTORY.

Fifteen years ago the Biological Club of the Ohio State University began publishing THE OHIO NATURALIST. This Journal has had a continuous existence and has been an important medium in advancing the knowledge of the natural history of the state. A number of years ago the NATURALIST became the official organ of the Ohio Academy of Science and was thus sent to every member of the Academy. At that time the Ohio Academy was largely composed of Biologists and Geologists, but has now widened its scope to include Physicists, Mathematicians, and others. It was, therefore, thought desirable by many that the scope of the NATURALIST should be enlarged so as to make it representative of all of the activities of the Academy. In accordance with this desire, committees were appointed by the various departments interested and a plan for future publication was proposed which was finally adopted.

The Ohio State University Scientific Society was thus organized at the Ohio State University and will take over the control of the new publication. This Society is to have somewhat the same relationship to THE OHIO JOURNAL OF SCIENCE as the Biological Club had to the Ohio Naturalist. The

management of the Journal is under an Editorial Board made up of representatives of various scientific departments of the University. This Board elects annually the Editor and two Associate Editors.

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THE OHIO JOURNAL OF SCIENCE is to be considered as a continuation of THE OHIO NATURALIST. It is hoped that with the wider field covered, it may interest a much larger number of the scientific people of the state, and be financially supported so that it may soon develop into a journal of high standard. It is the intention of the present Editors, with the large field before them, to publish results of research as well as articles of general interest in the advancement of Science. On the natural history side the aim at present will be to pay more especial attention to the biology, geology and geography of Ohio, but articles dealing with any other region will be acceptable.

The Editors for the present year are as follows:

John H. Schaffner—Editor.
James S. Hine—Associate Editor (Business).
Frederick W. Ives—Associate Editor (Subscriptions).

JOHN H. SCHAFFNER.

THE MAKING OF A PHOTOGRAPHIC OBJECTIVE.

Being a Description of a Course in Applied Optics Offered at the Emerson McMillin Observatory of the Ohio State University.

H. C. LORD.

Photography, in its more serious phase, has taken an important place in almost every field of human activity while in its lighter mood, through the development of the "Kodak" and the roll film, is giving us one of our most delightful pastimes. As a condition for the best work, a high grade lens is a necessity and especially so for those extremely short exposures required in the photography of rapidly moving objects. It often happens that some of the most perfect and at the same time most difficult specimens of optical design are found on cameras so small that they can be easily carried in one's coat pocket. These so called anastigmats furnish to the optician a difficult and yet at the same time most fascinating problem for mathematical investigation. Thousands of photographic objectives are placed on the market every year, yet though almost every branch of engineering is covered by our technical schools, I know of no place outside of Germany where a student can be instructed in the design and construction of a simple photographic objective. Professor Silvanus P. Thompson in his inaugural address as President of the British Optical Convention held in London in 1912, states: "In the Universities and Colleges the only people who are learning Optics are merely taking it as a part of Physics for the sake of passing an examination for a degree, and care nothing for the application of Optics in the industries. They are being taught Optics by men who are not opticians, who never ground a lens or calculated even an achromatic doublet, who never worked an opthalmoscope or measured a cylindrical lens." Further on he speaks as follows: "What is wanted is an establishment where the whole atmosphere is one of optical interest; where theory and practice go hand in hand; where the mathematician will himself grind lenses and measure their performance on the test bench; where braincraft will be married to handcraft; where precision, whether in computation or workmanship, will be the dominating ambition."

Some four years before the above quotations were written, the author started to work up a course in Optics which should aim, not only to give to the student a knowledge of the fundamental theory of lenses, but should also apply those principles to the methods of optical design and thus enable him to compute the curves of the component lenses of a photographic objective. This has now been fairly well worked out and is given in the Arts college under the official titles "Astronomy, 107, 108, 109 and 110." The basis of this course is "A System of Applied Optics," by H. Dennis Taylor, the inventor of the Cooke lens. This splendid volume develops, from the standpoint of geometric optics, a complete discussion of the formation of an image by a combination of any number of lenses, but does not apply the methods and formulae there developed to the actual design of a photographic objective. The writer of this paper was, therefore, compelled to work out this part of the theory for himself and, as he had always felt that all mathematics should ultimately end in arithmetic and that all arithmetic should ultimately end in doing something, he resolved at the outset that the course should end in laboratory work in the actual computation, grinding and polishing of lenses. As to how well this has succeeded, I will let the illustrations which accompany this article speak for themselves. Suffice it to say that the half tone cuts were made from five by seven enlargements from negatives, one and three quarters by two and one-eighth inches, taken with a lens *designed* and *built* at this observatory and working at an aperture of F six. A peculiar feature of this lens is that it is composed of four lenses all cut from the same piece of crown glass. This lens beautifully illustrates the importance of adding to the theoretical side of the course, the practical work in the laboratory in construction and testing as this lens, though in the main satisfactory, has one serious defect and a defect which is very instructive in that it shows that at a certain point in the design, the theory was weak and needed to be extended and enlarged. It should be stated that this theoretical investigation is now completed and ready to be put to the test of practice.

This Observatory possesses a well equipped instrument shop, which was used for the practical side of this work and it has seemed to me that a description of how we used the ordinary tools of a machine shop, of what special appliances we were

compelled to make, and how we finally ground and polished our lenses would be of general interest. These methods do not pretend to be the best, nor those actually employed by the manufacturer, but they do illustrate how a lens can be made and how a little ingenuity will enable one if he has the standard tools of a machine shop to carry out almost any kind of experimental work.

As a preliminary to this, a brief outline of the problem before the lens designer may be of interest. A simple lens consists of a piece of glass bounded by either plane or spherical surfaces as these, except in large reflecting surfaces, are the only kind that can be made with sufficient accuracy. Such a lens would have a great many defects or errors and would be unable to give a sharp image on the photographic plate unless stopped down to a very small aperture. By changing the radii of the surfaces, and the thickness of the lens, the designer can vary these errors, but after all is said and done he can do but little to improve the single lens. He then combines lenses of different forms and of different kinds of glass into a single objective, in this way making the positive errors of some of the lenses balance the negative errors of the others, until he arrives at a combination which is more or less perfect according to his skill as a designer. How this is accomplished is far beyond the limits of this paper, so I will now proceed to the mechanical side of the problem.

The first consideration is the glass; of course it must be what is known as optical glass and its selection is really part of the work of the designer. Optical glass is nothing more than a very perfect kind of glass which has been exquisitely annealed. You are all familiar with the intense green of window glass when seen edgewise; a piece of white paper will hardly be changed in color when seen through twelve inches of a good optical crown. The best optical glass is not made in this country, but must be purchased from either Schott & Gen. of Jena or Mantois of France. The Jena glass has become very celebrated and most of the lens makers state that their lenses are made out of it and as a consequence most people think that Jena glass means a certain kind, while, as a matter of fact, their catalogue for 1909 shows about seventy different varieties. These differ in optical qualities and chemical composition, and cost from about a dollar to five dollars a pound, with a few special varieties

costing as much as fifteen dollars. This glass comes in slabs, but will be cut by the makers with either a diamond saw or a sand saw, the purchaser paying for the "saw dust."

The slabs that were used here were 2″ x 6″ x ½″ and the first operation was to cut from these round disks a little larger than the finished lens. This was accomplished in the following manner and is illustrated in Fig. 1. In the chuck of a drill speeder on a Barnes drill press was placed a ¼″ steel rod which

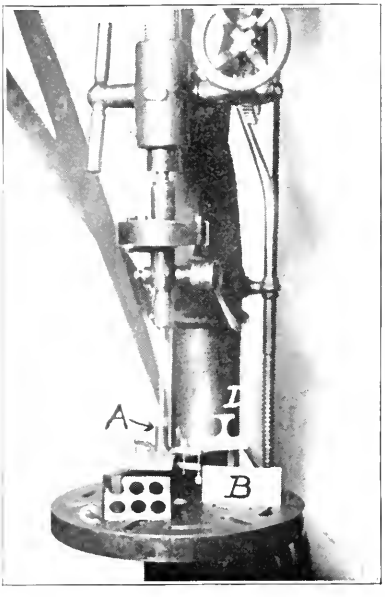

Fig. 1

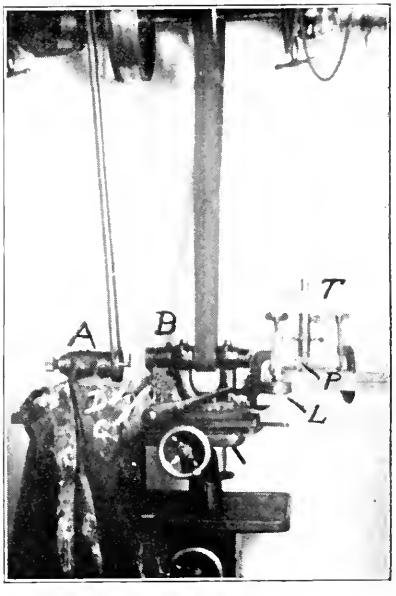

Fig. 2

carried at its lower end a copper tube, A, which was steadied at the bottom by a steel washer, bored to a loose fit to the tube, and clamped to the glass as shown. Number 40 Carborundum was used and lubricated with *plenty of water*. The tube must be lifted frequently to allow the abrasive to flow to the cutting edge. This is done so often that it seems almost a continuous motion of lifting and pressing down again, the tool resting on the glass hardly more than two or three seconds at a time. The cutting may be done at such a speed as to allow of a slight heating. As soon as the tube has cut itself about a sixteenth of an inch into the glass, the guiding washer may be removed and

the glass will then act as its own guide. A disk about one inch in diameter and a half of an inch thick could be cut out in a little over a half of an hour. At B Fig. 1 is shown one of the uncut slabs and at C and D two that are about used up. Though working rather slowly this proved quite satisfactory though wasteful of glass as it cut a rather wide scarf, copper must be used; brass was tried but the wear was so great as to render it almost useless while the copper shows almost none.

As these disks are cut out they are not only cone shaped but the edges are very rough so that the next operation was to grind these to smooth and true circular disks. This was done on a Wells tool grinder shown in Fig. 2, which was slowed way down by placing a large pulley on the counter shaft. The glass to be ground was held by cementing it with pitch onto a piece of brass rod which in turn was held in the drawing collet of the head A. A special wheel B, made by the Norton people for grinding the rims of spectacle lenses, was used and the machine slowed until the wheel would keep wet when running against a sponge, C, resting in water. The glass disk was in this way kept dripping and heating entirely prevented. The grinding was then carried out just as with any other material and the edge was made beautifully smooth and true in a few minutes. The beauty of pitch as a cement for holding the glass is that a slight heating will soften it so that the disk can be shifted to any position and then a dash of cold water clamps it in place and at the same time the pitch will slowly yield to the slightest pressure so that in a few minutes the glass is entirely free from strain. In manufacturing this sort of work is done with a diamond and is of course done much more quickly.

The disks were thick enough to make two lenses each so we sawed them into two as illustrated in Fig. 3. A is an old polishing head upon which was mounted a pulley at one end and a copper disk, B, at the other, the disk being held between large washers. C is a cast iron box fastened to an arm, D, hinged at E and kept pressed against the copper disk by a cord passing over two pulleys on the ceiling. This made a most excellent automatic feed. The glass to be split was fastened to a block of pine with pitch and the wood held in the iron box, C, with wedges. Number 40 Carborundum was used with plenty of water and the glass was cut through faster than a power hack

saw would cut through steel. The glass should be cut half way through and then reversed so that the final break will come in the middle and thus prevent the edges from spawling off. The chief defect of this machine was the way it scattered emery.

The disks are now ready for the grinding which is done on the machine on the right of Fig. 3, which consists simply of a vertical spindle run by a quarter twist belt from the counter shaft against the wall. The end of this spindle is tapered at

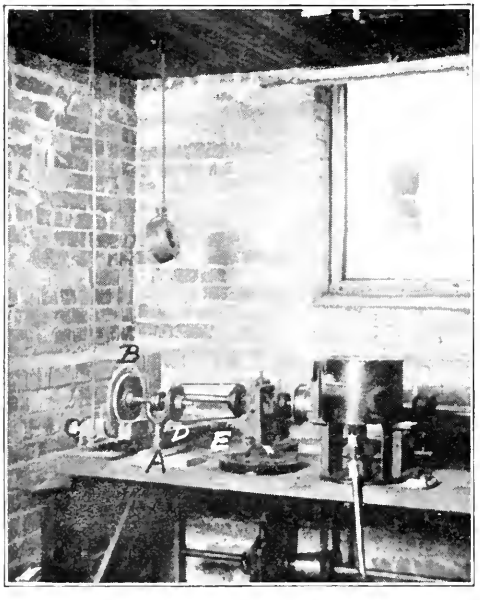

FIG. 3

the upper end to receive the grinding tool or laps, shown on the table in Fig. 5 which also shows the spindle raised so that the grinding lap is seen above the tin box, C, which surrounds the spindle to catch the abrasive that is thrown off in grinding. The glass is first smoothed down on a flat lap until it is of equal thickness at all points as measured by a micrometer when it is ready to be ground to the proper curves. For this purpose the spherical laps, shown in Fig. 5, are turned in the special machine illustrated in Fig. 4. The compound rest of an old Seller's lathe was removed and in its place, on the cross slide of the

carriage, was mounted the sphere turning rest. This consists of a base, A, in which the slide, B, is so mounted that it can be rotated about the center, C, by turning the milled head, D, which carries a worm at the opposite end. E is the tool post with the cutting tool T and L the lap to be turned. A hole was drilled at C into which was fitted a round piece of steel the upper end being pointed and then half cut away like a center reamer. This was used in finding the zero; the rod, pointed

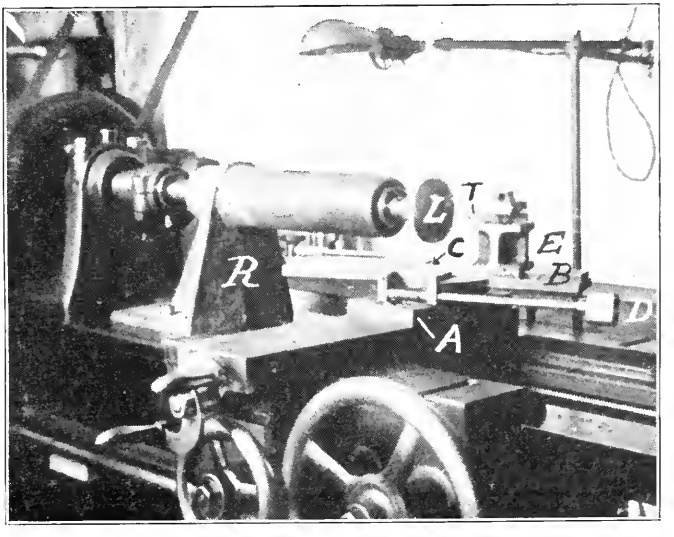

FIG. 4

end up, was placed in the hole at C and the cutting tool adjusted against the flattened side. The zero position is then determined by measuring, with an inside micrometer, the distance from the tool post to a stop placed at the end of the slide B. By adding to or subtracting from the zero reading of the micrometer the length of the radius of the grinding lap, the tool post may be set to the proper position for either a convex or a concave surface. This, however, is only approximate, for these laps must be made with the highest possible accuracy. After sufficient cuts have been taken to give a spherical surface, the radius is carefully measured with a special spherometer and the error in the radius corrected by changing the position of the cutting tool by an amount calculated from the readings of the

spherometer. This spherometer we were compelled to build as we could find none of sufficient accuracy on the market and it is described in a note at the end of this article.

In Fig. 4, R is simply a steady rest made with the large overhang to allow the slide B to swing under it in turning a convex surface. Two master laps, male and female, must be made and carefully ground together. Every effort should be taken to make these as accurate as possible since upon these

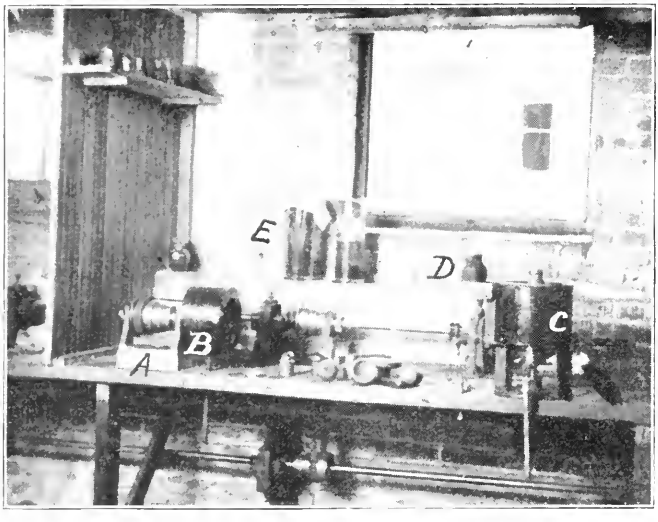

Fig. 5

depends the goodness of our lens. This special tool is easy to make and leaves nothing to be desired in its operation. Detail drawings and directions for making it are given in a note at the end.

We now come to the grinding or lapping of the lenses themselves. This is done in a lap turned as above and carefully fitted to the master laps and which must be trued from time to time as the work progresses. This lapping of glass is entirely different from the lapping of metals in that, while in metals the lap is to be kept almost free from the abrasive, in glass the lap must be freely supplied with emery and water or deep scratches will result. The best way to apply the emery is with a paint brush; the brush, saturated with emery, being held in front of

the lens as it is ground. The lens may be held in the hand or cemented to a disk of brass having a center hole drilled in the back in which is placed a pointed piece of steel held in the hand, the lens being free to rotate about the pointed steel holder. Of course where the lens has to be ground to a definite thickness it must be held by hand. Flour of emery was used to rough grind though coarser grades would have worked faster. The final smooth grinding was done with a special fine emery made for this purpose by Bausch and Lomb. Great care must be taken in the grinding to keep the lens as nearly centered as possible. A lens is said to be centered when the line which joins the centers of curvature of the surfaces passes through the center of figure. Obviously if a double convex lens could be ground to a knife edge it would be centered but if this were done the edge would be almost certain to crumble in the final polishing and deep scratches result. The centering of a convex lens can be watched by keeping the edge as nearly uniform of thickness as possible with a concave lens, if the original blank is made larger than necessary and care is taken to make the sides parallel, the centering can be watched by keeping a flat edge of *equal width* around the concave portion, the lens being placed back on the flat tool, from time to time, as the work progresses. If care is used the lens need be made but little larger than the finished size to allow for the final accurate centering to be described later.

After being smooth ground the lens is beautifully smooth and velvety to the touch but is just as much ground glass as ever, that is, it is absolutely opaque. We now come to the polishing. This is done with specially prepared rouge and only an excessively small amount of glass is taken off. Lord Rayleigh in a paper on "Polishing of Glass Surfaces" read before the British Optical Convention held in 1905, states: "I started with a finely ground surface, rather more finely ground I think than is used in practice, and I found that in order to obtain a pretty good polish it was necessary to remove a weight of glass, corresponding to a depth of about 6 wavelengths. I do not pretend that such a polish would satisfy the requirements of commerce; probably the 6 would have to be raised to 10 or 12 in order to get to the bottom of the deepest pits." When it is remembered that a wave length is about the fifty thousandth part of an inch we realize how very

delicate such lapping must be. For this work the lap is covered with pitch which has been brought to the proper degree of hardness either by boiling, to harden it or by adding asfalt varnish to soften it. The proper degree of hardness is very important and must be adjusted to the temperature of the room. Obviously if the pitch is too soft it will not hold its shape and it will be impossible to hold the polishing tool to the proper radius. I have put three different curves on a lens about an inch in diameter in a few minutes and it had to go back on the grinding machine before it could be finished.

The polishing tool is prepared as follows: A disk of pitch, about $^1_4$″ thick, is cast by pouring it in a mold made by a strip of brass bent to a circle, the ends clamped with a tool maker's clamp, and rested on a piece of cold cast iron which has been planed smooth. This should be of such size that when bent to the proper shape it can be molded over a tool similar to the grinding tool but with a radius changed by about the thickness of the pitch. This tool is then heated and painted with a stick of pitch, the disk is warmed, and the two pressed together, when cooled the pitch will stick tight to the iron but will be far from a smooth surface. This and the master tool of the opposite curvature are placed in warm water and pressed together and at the same time one slowly rotated, one about the other. When a good fit is secured they are cooled and a number of small holes, about 1–8″ in diameter, are drilled all over the pitch to distribute the abrasive, which of course spoils the surface and the tool must be again pressed. This pressing to shape must be done repeatedly and requires great care and some practice in order to have the pitch come to the exact opposite of the pressing tool. The most important thing is to do the pressing slowly and in fact in the whole process of this work one must never get in a hurry. Ritchey, in his memoir on the construction of the great 60″ at Mt. Wilson, recommends covering the pitch with beeswax, and for quicker and poorer work a cloth polisher may be used, the cloth being a special felt and cemented to the cast iron tool with a thin layer of pitch.

The abrasive is rouge or red oxide of iron and its preparation is fully described in the above mentioned work by Ritchey. We purchased the anhydrous red oxide of iron from Merck & Co. This was mixed with plenty of water in the jars shown at E, Fig. 5. The rouge will rapidly precipitate, the coarse particles

falling to the bottom, and leaving clear water above the precipitated rouge. The upper two-thirds of the rouge will be almost perfect and will give a beautiful polish when carefully siphoned off. This should be kept in tightly corked bottles, one of the best things is a horse radish jar as this has a place for the handle of the brush in the glass stopper, and all dust and grit can be easily washed off before the jar is opened. For polishing, the lens is cemented to a handle at whose end is a piece of brass turned to fit the lens in the sphere turning machine already described. Even in a small lens the polishing tool must be run slowly, the speeds of our machines run from 170 to 300 revolutions per minute and the fastest can seldom be used. The reason of this is that the lens fits the polisher so perfectly that almost a perfect vacuum is formed and the lens hugs the polished so closely that it is impossible to hold it in small sizes by hand alone and in the case of a convex surface, if the cavity is carried clear out to the edge of the glass disk, this may be broken simply by the friction due to this grip of the glass and pitch. Fig. 5 shows a horizontal polishing head at B and a vertical one at C. There is little choice except that for convex surfaces B seems the best, as it can be run faster, while for concave C seems better.

The lenses are now ready to be centered, that is, the circumference so turned that the line which joins the centers of curvature of the two spherical surfaces shall pass through the center of figure. In order to accomplish this, the lens is first cleaned from the pitch used to cement it to the handle used in holding the lens for polishing. For a long time I could find no way of doing this satisfactorily when pitch was the cement; finally, I laid my troubles before Dr. A. M. Bleile, Head of the Department of Physiology, and he suggested to first soak the lens in lard and then wash it in benzol (C_6H_6). This worked like magic though the first time I tried it I used some lard that had been heated with some pitch in it which made the lard very soft in fact almost as soft as it could be and yet not be an oil, and this same lard was used over and over again. The action is rather peculiar; the lard does not apparently effect the pitch at all but after a few minutes in the benzene it all flakes off and leaves the lens perfectly clean. The actual centering is then carried out on the grinding machine shown in Fig. 2; A holder, D, whose front face has been turned in the spherical turning

machine to fit one of the surfaces of the lens, is held in the head A. If the lens be cemented to this with a thin coat of pitch, it is obvious that the surface of the lens next to the holder will have its center of curvature coincide with the axis of rotation of the spindle of the head A, but the center of curvature of the other lens surface will probably fall outside of this axis. A lamp, L, has a tin chimney with a pin hole in it turned towards the lens, this pin hole forming a brilliant point of light, an image of which is formed by each surface and reflected by the total reflecting prism, P, into the telescope, T, where it is seen through the eyepiece. If the centers of curvature of both surfaces do not accurately coincide with the axis of rotation of the head, A, the images of the pin hole will describe circles as this axis is rotated. The back surface will of course be centered if the layer of the pitch used as cement is of uniform thickness which will generally be the case if the work has been carefully done; but in any case the image formed by it should be examined. If the front surface is out of center, as it generally will be, the holder should be warmed and the lens shifted, care being used to keep it tight against the surface of the holder as it is being shifted. As soon as both images remain stationary as the head, A, is rotated, the lens is fed against the wheel, B, and ground true and to size. This worked beautifully and the tests were wonderfully sensitive. As soon as the component lenses of the objective have all been thus centered, they are ready to be assembled in the cell or shutter in which they are to be used; but as this is simply a matter of careful machine work, I need not describe it further.

I know of no literature on the grinding of small lenses though the following memoirs on the making of large reflecting telescopes should be in the hands of any one interested in this work:

On the Construction of a Five-foot Equatorial Reflecting Telescope. By A. A. Common, LL. D., F. R. S. Memoirs of the Royal Astronomical Society, Vol. L., 1890-91.

On the Construction of a Silvered Glass Telescope, Fifteen and a Half Inches in Aperture, and its Use in Celestial Photography. By Henry Draper, M. D., Smithsonian Contributions to Knowledge, Vol. 34.

On the Modern Reflecting Telescope and the Making and Testing of Optical Mirrors. By George W. Ritchey. Smithsonian Contributions to Knowledge, Vol. 34.

NOTE 1—A SPHEROMETER FOR SHORT RADII.

In Fig. 6, A is a regular Brown & Sharpe Micrometer Head with the measuring point ground to an angle of 60° and slightly rounded; B is a round steel base all machined at one setting in which the micrometer head is clamped by a set screw not shown.

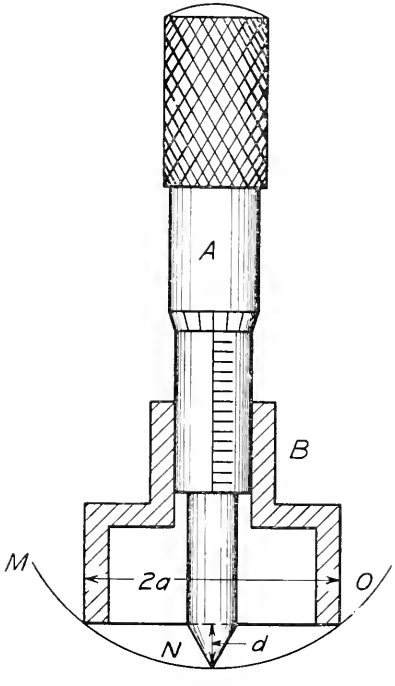

FIG. 6

Let r be the radius of the spherical surface, MNO, and we will have at once $r=(a^2+d^2)/2d$. The advantage of this form of spherometer is that it is very easy to make the point of the micrometer exactly central with the base and the value of 2a can be accurately determined by means of an ordinary micrometer calliper. For a convex surface, 2a should obviously be the inside diameter of the base, B.

In using the instrument, two tables, one for concave and one for convex surfaces, should be prepared; these tables to give the power in dioptres for each one thousandth of an inch in the value of d. Using the American Optical Co.'s Standard Index, namely, μ equal to 1.5000 and one dioptre as being the power of a lens of 40 inches focus, we have, for a plano lens, $p=40/f=40d/(a^2+d^2)$ since $f=r/(\mu-1)$.

The advantage of forming the table in dioptres in place of radii directly is that the tabular differences are small at all parts of the table so that interpolation can be readily done and this is not the case in tables which give the radii directly.

If upon measuring the radius of the tool or lap being turned in the sphere turning machine, Fig. 4, with this spherometer, the tool is found to be in error by an amount $\triangle p$ this may be corrected by changing the position of the cutting tool by an amount $20\triangle p/p^2$.

NOTE 2—CROSS SECTION OF THE SPHERE TURNING REST.

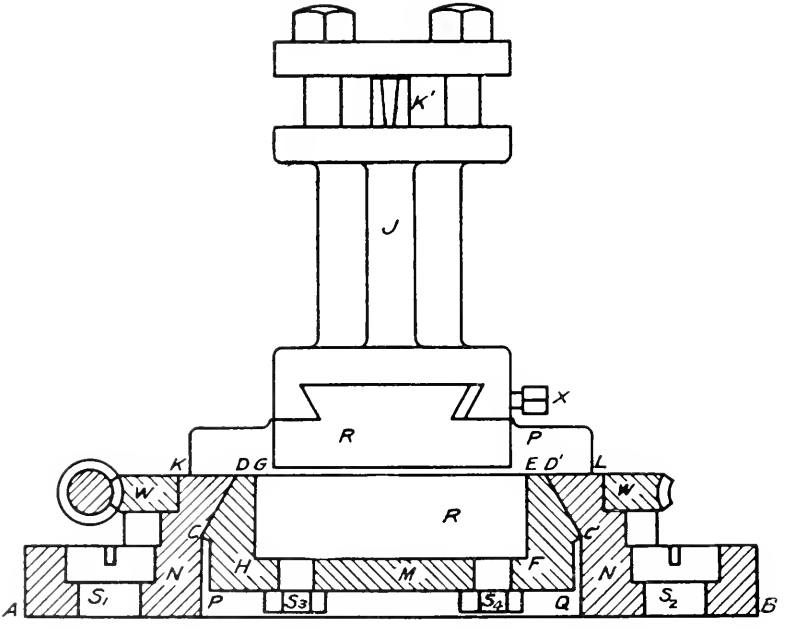

FIG. 7

In Fig. 7 is shown a cross section of the sphere turning rest further illustrated in Fig. 4. In machining this the following suggestions should be followed. The piece M should be cast with a lug projecting from the face PQ to chuck it by and all the turning done at one chucking. It should be made a close fit to R and bolted tight against DG and ED' with the bolts S_3 and S_4, clearance being given along the line HF. To compensate for ware the face DG and ED' can be releaved from time to time with a file. The base N, should be planed along AB, where it fastens to the cross slide of the carriage, then bolted to a face plate of the lathe and finished, care being used to leave the setting of the compound rest unchanged between machining the faces CD and C'D' of the pieces M and N. The dove tail on R should be first planed and then this bolted to a face plate and the boss GHFE and the faces KG and EL turned at one setting. If these directions are followed almost no hand work will be needed. W is a brass worm wheel held by screws not shown and J is the sliding tool post clamped at X with the tool at K'.

NOTES ON THE ZYGNEMALES.*

EDGAR NELSON TRANSEAU.

The following notes principally concerning North American Zygnemales are based on a study of the specimens accumulated in the course of eight years collecting in central Illinois; a collection made by Mr. Charles Bullard, of Cambridge, Mass., in Massachusetts and New Hampshire; the specimens distributed in the Phycotheca Boreali-Americana by Collins, Holden and Setchell; the specimens distributed in American Algae, by Miss Josephine E. Tilden; the specimens in the U. S. National Herbarium; and small collections sent me by Professor Farlow, Miss Tilden, Professor A. B. Klugh, Professor D. S. Johnson and Miss Grace Stone. They have been compared with the species distributed by Wittrock and Nordstedt in their "Algae Aquae dulcis exsiccatae," and other valuable European and South American specimens sent me by Professors O. Borge and O. Nordstedt.

In determining almost any species of the Zygnemales it is absolutely essential that the specimens show both the vegetative cells and the mature spores. With the exception of a few species of Mougeotia the spores are colored either yellow, brown, or blue when they are mature. The characteristic markings of the median spore wall do not develop usually until this color appears. Consequently it is useless to attach names to vegetative specimens based on dimensions and number of chromatophores. Keys based on such characters are not only useless, but misleading.

Judging from my experience in Illinois it is highly probable that the list of North American forms will be considerably augmented, when intensive studies have been made at localities in the Southern United States. The most satisfactory method of collecting these forms is to take samples from the various ponds and streams at regular intervals of ten days, or two weeks, throughout the growing season. Many of the species show local variations and considerable experience is needed before many

*Contribution from the Botanical Laboratory of the Ohio State University, No. 91.

of the forms can be satisfactorily classified. The writer has in course of preparation an illustrated key to the group, in which figures for all of the species will be published.

DEBARYA Wittrock.

This genus is in many respects the most generalized of all the *Zygnemales*. It is distinguished by three important characteristics: (1) the entire contents of the gametangia enter into the making of the zygospore; (2) the zygospore is formed in the conjugating tube and is not cut off from the other parts of the gametangia by partition walls; (3) as the gametes move toward the tube during conjugation, their place is taken by a secretion of cellulose, which renders the gametangia solid and highly refractive. This secretion also occurs when a vegetative cell forms an aplanospore.

Debarya glyptosperma Wittrock.

This species has been recorded for America. It is not uncommon in Massachusetts and has also been found in Minnesota and Florida. In P. B.-A. No. 808 from Boswell, California is a somewhat smaller variety with blue spores associated with *Zygnema peliosporum* Wittr. The spores are common in the material and the vegetative cells and filaments occasional. Following is a diagnosis for this variety:

Var. **formosa** nov. var. Cellulis vegetativis 7.5-9μ latis; zygosporis 24-30μ x 30-42μ, caeruleis; ceterum ut in typo.

Vegetative cells 7.5-9μ in diameter, zygospores 24-30μ x 30-42μ steel blue, otherwise like the type.

Debarya americana nov. sp.

Cellulis vegetativis 9-12μ x 27-120μ, ad dissepimenta constrictis; chromatophoris cum pyrenoidibus 2; cellulis fructiferis 10-14μ x 75-180μ; zygosporis ovoideis vel quadrato-ovoideis, 20-40μ x 30-40 μ, angulis rotundatis, productis, vel retusis; parthenosporis 15-20μ x 20-30μ, oblique ellipticis, cum polis retusis; mesosporio subtiliter et irregulariter verrucoso, maturitate luteo-brunneo.

Vegetative cells 9-12μ x 27-120μ constricted at the end walls, chromatophore with two pyrenoids; fertile cells 10-14μ x 75-180μ; zygospores ovoid or quadrately ovoid, 20-40μ x 30-40μ, with angles rounded, produced, or retuse; parthenospores 15-20μ-

x 20-30μ unilaterally ellipsoid with retuse ends; median spore wall minutely and irregularly verrucose, yellow-brown at maturity.

This species was collected by Professor A. B. Klugh, Kingston, Ontario. It is the material upon which the Ontario record for *Mougeotia calcarea* (Cleve) Wittr. is based. Of special interest is the chromatophore with two pyrenoids, which although an axile plate is distinctly two-lobed and forms an easy transition to the next species, in which the chromatophore resembles *Zygnema*. Type in herb. E. N. T. Collection No. 2950.

Debarya decussata nov. sp.

Cellulis vegetativis 16-20μ x 25-50μ cylindraceis; chromatophoris asteroidiis duobus, singulis cum pyrenoidibus (ut in Zygnemate); zygosporis vel ovoideis, vel irregularibus, 24-30μ x 30-48μ cum angulis vel rotundatis, vel retusis, vel productis; aplanosporis uno latere ovoideis, 17-25μ x 20-40μ; parthenosporis 15-20μ x 20-30μ; membrana media sporarum scrobiculata, luteo-brunnea; akinetis ad dissepimenta constrictis, membrana suberassa et glabra, 18-20μ x 20-36μ.

Vegetative cells 16-20μ x 25-50μ cylindrical; chromatophores two, stellate, each with a pyrenoid (as in Zygnema); zygospores ovoid, quadrate-ovoid, or irregular, 24-30μ x 30-48μ, with rounded, retuse, or produced angles; aplanospores unilaterally ovoid, 17-25μ x 20-40μ; parthenospores 15-20μ x 20-30μ; median spore walls scrobiculate, yellow-brown; akinetes with smooth heavy walls, 18-20μ x 20-30μ.

Type in herb, E. N. T. Collections No. 1177, 1939, 1949, 2686 and 2918. I have specimens from several localities in central Illinois; Williamsport, Pa.; Minnesota; Mackinaw, Mich. and Kingston, Ontario.

This form is of great interest because of its resemblance, in the vegetative condition, to *Zygnema decussatum* (Vauch.) Transeau. Also because it shows not only the zygospores, but aplanospores and parthenospores. In all cases the secretion of cellulose accompanies the process of spore formation. The unilaterally placed aplanospores are strikingly different from those formed by the Zygnemas. In some of the Illinois ponds it regularly produces only zygospores, in other ponds from which I have collections covering a period of several years it

fruited only asexually, producing aplanospores and akinetes. But several of the collections show all the forms of reproduction in different cells of the same filament.

The characteristics of this species suggest that the peculiar *Zygnema reticulatum*, which was described by Hallas in 1895*, is in reality a *Debarya*. The fact that the reproductive cells become filled with cellulose, that the aplanospores are very irregular in form and that the vegetative cells contain as high as seven chromatophores, are all in harmony with this idea. On this basis it is also easy to understand the most notable peculiarity of the species—that spores derived from cells with several chromatophores produce two or three sporelings.

With the addition of the two new American species and this Danish species **Debarya reticulata** (Hallas) nov. comb. the description of the genus needs to be modified as follows:

Vegetative cells cylindrical or constricted at the ends, varying from 1-16 diameters in length; chromatophore varying from an axile plate with two or more pyrenoids to stellate chromatophores, each with a central pyrenoid. Reproduction by zygospores formed of the complete contents of the gametangia; not cut off from the gametangia by partition walls; but in the process of conjugation, as the gametes pass into the conjugating tube, their place is taken by a secretion of cellulose. Aplanospores occupying only part of the sporogenous cell, the remainder being filled with cellulose. All spores variable in form. Parthenospores and akinetes occur not infrequently in some of the species. The walls of the aplanospores and parthenospores resemble the zygospores of the same species in their markings.

There are now eleven described species belonging to this genus. *D. immersa* W. West and *D. africana* G. S. West bear a close resemblance to *Mongeotia sphaerocarpa* Wolle. *D. Hardyi* G. S. West has much the same appearance as *Mongeotia viridis* (Kutz) Wittrock. *D. desmidiodes* W. & G. S. West, *D. calospora* (Palla) W. & G. S. West, *D. reticulata*, *D. americana*, and *D. decussata* have characters in common with the Zygnemas. *D. glyptosperma* has the vegetative characters common to several of the species, but its spores are quite unique among the *Zygnemales*.

*Hallas, E., Om en ny Zygnema-Art med Azygosporer. Bot. Tidsskrift 20:1-16. 1895.

ZYGNEMA Agardh.

Z. pectinatum (Vauch.) Agardh.

This is probably common in the eastern half of the United States at least. In Illinois along with the type occurs the variety *conspicuum* (Hass.) Kirchner, and a variety with large spores. This latter variety in fact is more common than the type.

var. **crassum** nov. var. Cellulis vegetativis 30-40μ x 20-80μ; zygosporis 40-55μ x 50-60μ, ceterum ut in typo.

Vegetative cells 30-40μ x 20-80μ; zygospores 40-55μ x 50-60μ, otherwise like the type. Type in herb. E. N. T. Collections No. 2350, 2392, 2660, 2685.

Z. ericetorum (Kütz) Hansgirg.

Professor G. S. West has studied the reproduction of this species and finds that it is a true Zygnema and that the description and figure by De Bary, which shows the cutting off of two special gametangia before the union of the gametes is at fault, consequently there is no longer any need of maintaining the genus *Zygogonium* Kützing.

Z. peliosporum Wittrock.

Specimens of this species have been distributed under the name of *Z. chalybeospernum* Hansgirg, in P. B.-A. No. 808 from Boswell, Calif. (N. L. Gardner); Amer. Alg. No. 156 from Ft. Collins, Colo. (J. H. Cowan); and Amer. Alg. No. 392 from Vancouver, B. C. (J. E. Tilden). *Z. chalybeospermum* has the median wall smooth, but the spores of all of the above specimens have distinctly scrobiculate median walls. In size the specimens show a somewhat greater variation in dimensions than has been recorded for European localities.

Z. cruciatum (Vauch) Agardh.

Specimens of this species have been found at Fath Pond, north of Coffeen, Ill., in which both zygospores and aplanospores occurred in abundance. The aplanospores fill or slightly enlarge the vegetative cells as in *Z. Collinsianum* Transeau,* but the ends of the spores are usually more nearly truncate, 34-50μ x 30-80μ. At Casey, Ill., a variety with the same dimensions but steel blue spores occurs in the old Ice Plant Pond.

*See Fig. 3, Plate XXV, Amer. Jour. Bot. 1:301. 1914.

var. **caeruleum** nov. var. Cellulis vegetativis et sporis ut in typo, sed membrana media sporarum caerulea.

Vegetative cells and spores as in the type, except that the median spore wall is steel blue. Type in Collection E. N. T. No. 495.

Zygnema stellinum (Müller) Agardh.

The specimen distributed under the name *Z. insigne* (Hass.) Kütz. in the P. B.-A. No. 457, from Chestnut Hill, Mass. (G. F. Moore), belongs to this species as shown by the scattered mature spores. This species is common everywhere in central Illinois. In the U. S. Natl. Herb. is a specimen from Baltimore Co., Md., (J. D. Smith). In Amer. Alg. No. 157, a specimen from St. Paul, Minn., (J. E. Tilden) shows both zygospores and aplanospores. The aplanospores are cylindric ovoid in form, occupying the entire cell 30-33μ x 40-88μ, median wall scrobiculate.

Zygnema cylindricum nov. sp.

Cellulis vegetativis 28-33μ x 28-66μ; zygosporis incognitis; aplanosporis cylindricis vel tumido-cylindricis, 30-33μ x 24-58μ, sporangia complentibus; membrana media brunnea scrobiculata.

Vegetative cells 28-33μ x 28-66μ; zygospores unknown; aplanospores cylindric or tumid-cylindric, 30-33μ x 24-58μ, filling the sporangia, median wall brown, scrobiculate. Type in Herb. E. N. T. No. 1164, 1177.

This species is not uncommon in ponds, and pools throughout central Illinois. It was at first classified as aplanosporic material of *Z. stellinum* (Müller) Agardh. On going over the specimens in all my collections, however, it was found that in no case were the filaments containing the aplanospores connected with the filaments containing zygospores. This must be the final test of the identity of the species, as it occurs in some collections alone, sometimes associated only with fruiting *Zygnema pectinatum*, and sometimes with *Z. stellinum*.

Zygnema rhynchonema Hansg.

In a collection of algae made at the Minnesota Seaside Station, Vancouver Island, B. C., in 1901, by Professor Tilden, is a form which perhaps belongs here. The vegetative cells are from 22-28μ in diameter, and 32-52μ in length, while the European specimens are described as 16-20μ in diameter and

2-6 diameters long. The Vancouver specimens are producing both aplanospores (globose, 24-26μ in diam.), and zygospores (ovoid 24-28μ x 36-44μ) by the union of gametes through the partition wall separating the two gametangia. The specimens show some evidences of being in an abnormal condition.

SPIROGYRA Link.

S. Juergensii Kützing.

The specimen in P. B.-A. No. 510 from Knightsville, R. I., distributed under the name of *S. longata* (Vauch) Kütz. with cell diameter 27-30μ, and ellipsoid spores 30-33μ in diameter, fertile cells enlarged, evidently belongs to this species. The spores of *S. longata* are distinctly ovoid with rounded ends. In the Illinois specimens the spores of *S. Juergensii* frequently occur with diameters up to 33μ.

S. varians (Hass.) Kütz.

The varieties *scrobiculata* Stockman and *minor* Teodoresco have not been reported from America. They both occur rarely in Illinois. The latter I have also seen in material collected by Mr. Charles Bullard, at Lynnfield, Mass. The former is characterized by its scrobiculate spores, the latter by its smaller dimensions throughout. In my herbarium *S. varians scrobiculata* is represented in Collections No. 1799, and 1881; and *S. varians minor* in Collection No. 2951.

S. Borgeana nov. sp.

Cellulis vegetativis 30-35μ x 50-200μ, dissepimentis planis, chromatophoris singulis anfractibus arctis 1.5-5; cellulis fractiferis altero latere inflatis, altero latere (in quo conjugatio sequitur) rectis; zygosporis ellipticis, 33-40μ x 54-70μ, membrana media flava, glabra.

Vegetative cells 30-35μ x 50-200μ, end walls plane, 1 chromatophore making 1.5-5 turns; fertile cells inflated on the outer side, straight on the conjugating side; zygospores ellipsoid 33-40μ x 54-70μ, median wall yellow, smooth. Type in herb. E. N. T. Coll. No. 1883, 1890. Charleston, Illinois.

This species bears some resemblance to a form of *S. varians* figured by Professor Borge.* It differs from his figure in that the conjugating side of the fertile cells is not at all swollen,

*Borge, O., Beitrage zur Algenflora von Schweden.

and the dimensions are somewhat larger. If this form had been found but once it would have been passed over as a variation intermediate between *S. Juergensii* and *S. varians*. But it has been found several successive years in a small stream south, and at a small pond west of Charleston, Illinois.

S. lutetiana Petit.

So far as I am aware no specimens of this species have been found in America. The Illinois record in my list* is an error. The P. B.-A. specimen labelled *S. lutetiana* is *S. fallax* (Hansg.) Wille, as shown by its often replicate cell walls, verrucose spores and the number of chromotophores.

S. velata Nordstedt var. **occidentalis** Transeau.

Specimens of this variety have been distributed in the P. B.-A. No. 96, under the name of *S. dubia* Kütz. var. *longiarticulata* Kütz. from Oak Bay, Victoria, British Columbia (N. L. Gardner). The spores are for the most part not mature but they show the characteristic scrobiculate markings of the median wall.

S. Lagerheimii Wittrock.

This species is not uncommon in central Illinois. The specimen labelled *S. communis* in P. B.-A. No. 1416, from Winchester, Mass., has a cell diameter over 30μ, and the spores are ellipsoid instead of ovoid. The median spore wall in the mature spores is punctate. Here also belongs the P. B.-A. specimen No. 365, Falmouth, Mass. Both the vegetative cells and the spores are considerably below the lower dimensions for *S. porticalis*. The P. B.-A. specimen No. 1668, *S. porticalis* var. *tenuispira* Collins establishes this name as a synonym of *S. Lagerheimii*. Professor Farlow has recently sent me a specimen of this species from Chocorua, N. H.

S. daedalea Lagerheim.

This species has recently been found in a pond south of Coffeen, Ill. The spores show the characteristic markings and the dimensions are near those of the original collection. The spores are slightly more rhomboidal than in the type material, which I have seen. In herb. E. N. T. Collection No. 2912, 2850.

*Transeau, E. N., Annotated list of the Algae of Eastern Illinois. Trans. Ill. Acad. Sci. 6:69-89, 1913.

S. Goetzei Schmidle.

This species previously known only from the tropics has been found in the collection of Mr. Charles Bullard, from Wellfleet, Mass. In herb. E. N. T. Collection No. 2954.

S. submarina (Collins) nov. comb.

This species was described by Collins as a variety of S. *decimina* (Müller) Kütz. which it somewhat resembles in the form of the vegetative cells. The spores, however, are distinctly ellipsoid, while those of *S. decimina* are ovoid. The dimensions are much smaller than those of *S. decimina*. It seems better therefore to recognize this as a distinct species. It has been collected in Massachusetts, Connecticut and Bermuda.

E. ellipsospora Transeau.

Described originally from Illinois, I have seen specimens during the past year from Maine, Massachusetts and Minnesota. Professor G. S. West* described about the same time a species from Columbia, South America, which appears to be a form of this same species. The vegetative cells are considerably larger, the chromatophores are six (or five) in number, and the spores are at the upper limit of size of the North American form. As our specimens all show, a wider range of dimensions and number of chromatophores, the South American form is best classified as a variety under the name *S. ellipsospora* var. **splendida** (G. S. West) nov. comb.

S. propria nov. sp.

Cellulis vegetativis 60-68μ x 80-150μ, dissepimentis planis; chromatophoris 3, anfractibus arctis .5-1; cellulis fructiferis cylindricis; zygosporis ellipticis 42-60μ x 80-120μ; membrana media sporarum scrobiculis irregularis ornata, luteo-brunnea.

Vegetative cells 60-68μ x 80-150μ, end walls plane; 3 chromatophores making .5-1 turn in the cell; fertile cells cylindrical; zygospores ellipsoid, 42-60μ x 80-120μ, median wall irregularly pitted, yellow-brown. Type in herb. E. N. T. Coll. No. 2666. Coffeen, Illinois.

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*West, G. S., A contribution to our knowledge of the Freshwater Algae of Columbia. Memores de la Societe neuchateloise des Sciences Naturelles 5:1013-1051. Neuchatel, 1914.

This species is very distinct in the form of its spores and their position in the fertile cells. Lateral conjugation only has been observed. It is possible that the number of chromatophores is more variable, but in all the vegetative cells in which they could be counted there were three.

Spirogyra braziliensis (Nordstedt) nov. comb.

Owing to the indefinite and imperfect description of *S. lineata* Suring., the variety *Braziliensis* Nordstedt, of which we have a perfect description and specimens (W. & N. Alg. aq. dulc. exsicc. No. 360), should be given specific rank. Its connection with *S. lineata* is very problematical.

S. fluviatilis Hilse.

In all the published descriptions of this species the spores are described as smooth, and the number of chromatophores is given as four. I have seen many specimens from Illinois, and collections from the upper peninsula of Michigan (T. L. Hankinson), Minnesota (J. E. Tilden), Hawaii (J. E. Tilden), Massachusetts (P. B.-A. No. 1217), Pennsylvania (E. N. T.) and Guatemala (W. A. Kellerman). In all cases the mature spores are brown and scrobiculate, and the number of chromatophores is three or four.

S. nova-angliae nov. sp.

Cellulis vegetativis 50-60μ x 200-350μ, dissepimentis planis; chromatophoris 3-5, anfractibus arctis 2.5-4.5; cellulis fructiferis non inflatis; zygosporis ovoideis 50-65μ x 80-120μ: membrana media sporarum reticulata et dense punctata, flava.

Vegetative cells 50-60μ x 200-350μ, end walls plane; 3-5 chromatophores making 2.5-4.5 turns; fertile cells not inflated; zygospores ovoid 50-65μ x 80-120μ: median wall reticulate and densely punctate, yellow in color.

This species was first found in the collections of Mr. Bullard from Beaver Dam, Brook Pond, Natick; the pond west of Winter Pond, Winchester; and the Middlesex Fells, Mass. Recently the same form was found in a large prairie pond south of Coffeen, Illinois. Its position in the genus is near *S. malmeana* Hirn. In herb. E. N. T. Collections No. 2952, 2953 and 2900.

S. diluta Wood.

I first came across this species in Mr. Bullard's collection from the pond west of Winter Pond, Winchester, Mass. On going over Wood's description, its identity with *S. diluta* is unmistakable. The position, color and form of the spore, and the shape of the fertile cells is perfectly represented in Wood's figure. The dimensions also correspond. Wolle is responsible for confusing this species with *S. nitida* (Dillw.) Link, but a glance at Wood's figure is sufficient to show that it is very different from that species. The P. B. A. specimen No. 513 (labelled *S. nitida*) from Bridgeport, Conn., belongs here. Miss Grace Stone also sent me a collection of this species from near New York City. In the U. S. National Herbarium is another specimen from Bois Sabbi, Louisiana, April 7th, 1891, (A. B. Langlois). Recently the species has been collected at Donnelson, Illinois, by Mr. Frank Harris.

The vegetative cells are usually shorter than in *S. nitida*, the spores are ovoid, not ellipsoid, and the spore wall is verrucose, or reticulate-verrucose, chestnut brown in color. In herb. E. N. T. Coll. No. 2900.

S. crassa Kützing.

Var. **formosa** nov. var. Varietas gracilis, cellulis vegetativis 80-95μ x 80-270μ; zygosporis 88-100μ x 120-150μ x 70-90μ; ceterum ut in typo.

A small variety, vegetative cells 80-95μ x 80-270μ; zygospores 88-100μ x 120-150μ x 70-90μ; otherwise similar to the type. Type in herb. E. N. T. Coll. No. 1939. This variety occurs in a pond east of Ashmore, Ill.

S. submaxima Transeau.

This species which was described from Illinois has been found with nearly the same dimensions in the collections from Middlesex Fells, and South Peabody Station, Mass., sent me by Mr. Chas. Bullard.

S. micropunctata nov. sp.

Cellulis vegetativis 30-36μ x 120-300μ, dissepimentis planis, chromatophoris singulis anfractibus arctis 3-7; cellulis fructiferis modo binis vel quaternis inter cellulas vegetativas distributis, modo continuis, altero latere (in quo conjugatio

sequitur) inflatis, altero rectis; tubo conjugationis plerumque ex cellula mascula emisso; zygosporis ellipticis 37-42μ x 57-100μ membrana media micropunctata et lutea.

Vegetative cells 30-36μ x 120-300μ, end walls plane; 1 chromatophore making 3-7 turns; fertile cells scattered in twos or fours among vegetative cells, or continuous, inflated on the conjugating side, outer side straight; conjugating tubes formed almost wholly by the male cell, zygospores ellipsoid 37-42μ x 57-70μ, median wall minutely punctate, yellow. Type in herb. E. N. T. Coll. No. 2470, 2953.

This species was first found in the West Big Four Pond, east of Charleston, Illinois. It has since been found in a collection from Chocorua, N. H., sent me by Mr. Chas. Bullard. It evidently belongs in the *punctata* group of the Spirogyras, but in form and markings of the spore, and the shape of the fertile cells it is amply distinct from its nearest allies; *S. punctiformis* Transeau and the next species to be described.

S. reflexa nov. sp.

Cellulis vegetativis 30-40μ x 120-300μ, dissepimentis planis; chromatophoris singulis anfractibus arctis 3-8μ cellulis fructiferis binis vel quaternis inter cellulas vegetativas distributis, inflatis et valde reflexis; tubo conjugationis ex cellula mascula emisso; zygosporis ellipticis, 44-54μ x 90-150μ, membrana media glabra et luteo-brunnea.

Vegetative cells 30-40μ x 120-300μ, with plane end wall; 1 chromatophore making 3-8 turns; fertile cells in groups of 2 or 4, inflated or enlarged and strongly reflexed; conjugating tube formed by the male cells; zygospores ellipsoid, 44-54μ x 90-150μ, median wall smooth, yellow-brown. Type in herb. E. N. T. Collection No. 2661, 2664, 2912.

This species has been under observation for four years and has been collected from ponds near Casey, Lerna, Coffeen and Donnellson, Illinois. The large, smooth spores, the reflexed conjugating cells, and the tube produced wholly by the male cells are the distinguishing characteristics.

S. hydrodictya nov. sp.

Cellulis vegetativis 75-100μ x 210-360μ, dissepimentis planis, chromatophoris 7-10, modo subrectis longitudinalibus, modo spiralibus anfractibus arctis .1-.5; cellulis fructiferis inflatis vel

subinflatis; tubo conjugationis ex cellula mascula emisso; zygosporis lenticularibus vel globoso-lenticularibus, 80-120μ x 110-195μ, membrana media scrobiculis obsita, brunnea.

Vegetative cells 75-100μ x 210-360μ, end walls plane, 7-10 chromatophores, either straight, or spiral making .1-.5 turns; fertile cells inflated or subinflated; conjugating tube formed by the male cell; zygospores lenticular or globose-lenticular 80-120μ x 110-195μ, median wall brown, pitted. Type in herb. E. N. T. Coll. No. 2661, 2665. Coffeen, Illinois.

This is one of the most remarkable forms described in this genus. It combines large size, the lenticular spore form, and the habit of forming the conjugating tube entirely by the male cell. The conjugating tube has walls heavier than those of any known species. Conjugation is both lateral and scalariform, and occurs between scattered cells, very rarely continuous for 6-8 cells. In the fruiting condition the filaments form a meshwork which suggests the specific name. It has thus far been found only in the Fath Pond, north of Coffeen, Illinois.

S. protecta Wood.

A study of American specimens of this species from Massachusetts, Connecticut, New Jersey, Michigan and Illinois, shows that like *S. Grevilleana* there are always some cells with two chromatophores. I have twice found this species producing aplanospores.

S. tenuissima (Hass.) Kütz var. **rugosa** Transeau.

P. B.-A. specimen No. 456, Easton's Pt., Newport, R. I., belongs to this variety rather than the type, as shown by the scrobiculate spore wall. In Mr. Bullard's collection there are also specimens of the variety from Pennannock, N. J., and from Spy Pond, Lake St., Arlington, Mass.

S. Farlowii nov. sp.

Cellulis vegetativis 24-30μ x 70-180μ, dissepimentis replicatis; chromatophoris singulis, rarius duobus, anfractibus arctis 2.5-6; cellulis fructiferis inflatis (ad 39-60μ); zygosporis ellipticis, polis plus minus acuminatis, 32-45μ x 48-93μ, membrana media glabra, lutea.

Vegetative cells 24-30μ x 70-180μ, end walls replicate; 1 (rarely 2) chromatophore making 2.5-6 turns; fertile cells

inflated to 39-60μ; zygospores ellipsoid, ends more or less pointed, 32-45μ x 48-93μ, median wall smooth, yellow. Type in herb. E. N. T. Coll. No. 2955, 2956, 2957.

In Mr. Bullard's collection there are specimens of this species from Lexington, Arlington, and Middlesex Fells, Mass. The P. B.-A. specimen No. 362, labeled *S. Grevilleana*, from Medford, Mass., belongs here, rather than to *S. Grevilleana*, in which the spores are distinctly ovoid with broad rounded ends.

S. groenlandica Rosenvinge.

This interesting form is characterized by quadrately inflated fertile cells, highly refractive cell walls, and unusually long cells and spores. In Mr. Bullard's collection there are specimens from Stony Brook, South Framingham, Middlesex Fells, Wayside Inn, North Eastham, and Malden Fells, Massachusetts. The P. B.-A. specimen No. 363 labelled *S. inflata*, Orange, Conn., belongs to this species.

S. fallax (Hansgirg) Wille.

This species is one of several forms near *S. insignis* (Hass.) Kützing. If Wille's description is correct and identical with Hansgirg's material, then *S. inconstans* Collins becomes a synonym of *S. fallax*. Hansgirg's figure suggests that the filaments in his material are homosexual. While Wille's description and figure suggests that the filaments are reflexed and that conjugation does not regularly occur between parallel filaments, with the spores all in one filament. It is difficult to decide just where these rough-spored forms belong as the earlier authors did not pay much attention to spore markings. In this connection the note by Professor Nordstedt in connection with specimen No. 958 in Wittrock and Nordstedt's Algæ Exsiccatæ is of interest. Until these forms have been clearly separated by a study of the original collections it seems best to use *S. fallax* for *S. inconstans*, of which the type is P. B.-A. No. 1568. Here also belongs P. B.-A. No. 1570, Middlesex Fells, Mass., and P. B.-A. No. 1571, Wakefield, Mass.

S. floridana nov. sp.

Cellulis vegetativis 56-66μ x 120-335μ, dissepimentis planis; chromatophoris 4-5, subrectis vel anfractibus arctis .5; cellulis conjugatis abbreviatis, inflatis (ad 135μ) et geniculatis; canalis conjugationis brevis et latis; zygosporis ellipticis, 75-105μ x 95-135μ membrana media glabra, lutea.

Vegetative cells 56-66μ x 120-335μ, end walls plane; 4-5 chromatophores, nearly straight or making a half turn; conjugating cells geniculate, shortened; fertile cells inflated up to 135μ; conjugating tube very short and broad; zygospores ellipsoid, 75-105μ x 95-135μ median wall smooth, yellow. Type in U. S. National Herbarium, collected by J. D. Smith, in S. W. Florida, March, 1878.

In its dimensions *S. floridana* is intermediate between *S. stictica* (Eng. Bot.) Wille and *S. ceylanica* Wittrock. In several publications the statement is made that *S. ceylanica* is intermediate between *S. stictica* and the common forms of *Spirogyra*. A study of authentic material of this species has shown that it has not intermediate characters, but with its spores having a minutely pitted median wall, it seems to be intermediate between *S. floridana* and *S. illinoiensis* Transeau, the most specialized form in the Sirogonium group of the genus.

Throughout the study of these collections the writer has been greatly assisted by Mr. Hanford Tiffany, now a teacher in the Charleston, Illinois, High School. It is a pleasure to acknowledge my indebtedness to the many collectors who have sent me specimens for study.

ORGANIZATION OF THE OHIO STATE UNIVERSITY SCIENTIFIC SOCIETY.

As the result of the sentiment expressed at the 1914 meeting of the Ohio Academy of Science that the official organ of the Academy, "The Ohio Naturalist," should be broadened and made more comprehensive in scope, and feeling that the Ohio State University had no publication representing the scientific work being done at the institution, the members of the Biological Club of the University, in whom the publication of the "Ohio Naturalist" had been vested, called a meeting of representatives of the various departments interested in science at the university to discuss the advisability of publishing as successor to the "Naturalist" a journal to be known as the OHIO JOURNAL OF SCIENCE.

The first meeting was held in May, 1915, and committees appointed to outline preliminary plans. At subsequent meetings the reports of the committees were discussed, interest in the plan continued to develop, until at a meeting held October 13 the following self-explanatory Constitution was adopted. The society as now constituted represents twenty-four departments of pure or applied science at the university.

RAYMOND J. SEYMOUR,
Secretary Pro Tem.

CONSTITUTION.

Article I—Name.

The name of this society shall be the Ohio State University Scientific Society.

Article II—Object.

It shall be the purpose of the Society to promote scientific work in the University by holding meetings for the presentation and discussion of the results of scientific work; by co-operating with other agencies in arranging for scientific lectures and in the entertainment of visiting scientists and scientific societies; by publishing the Ohio Journal of Science and by furnishing opportunity for the discussion and promotion of any project of scientific interest which may properly come within the scope of such an organization and, in general, by furthering in every way possible the interests of scientific work in the University and the State.

Article III—Membership.

Any member of the instructional staff in the Ohio State University interested in scientific work shall upon application be eligible to election to membership in the Society. Students of the Ohio State University interested in scientific work shall be eligible to membership when endorsed by two faculty members of the society.

Article IV—Officers.

Section 1. The officers of the society shall consist of President, Vice-President, Secretary and Treasurer. These officers shall perform the duties common to such positions.

Section 2. The Executive Committee shall consist of the officers and the Editor of the Ohio Journal of Science. It shall have power to arrange programs for meetings, to represent the society when co-operating with other organizations and to conduct all affairs of the society not otherwise provided for.

Article V—Editorial Board.

The Editorial Board shall be responsible for the management of the Ohio Journal of Science. It shall consist of representatives, one from each department of science in the university represented in the society membership. This board shall elect annually an Editor and two Associate Editors.

Article VI—Elections.

Election to membership shall be by vote of the Executive Committee.

The officers shall be elected by ballot at the annual meeting in May. Nominations shall be presented by a nominating committee which shall consist of the Editorial Board.

One member of the Editorial Board shall be elected by each department from among the members of such department represented in the society and in case any department fails to elect a member for this board the Executive Committee shall elect for the department.

Article VII—Publication.

The Editor and Associate Editors of the Ohio Journal of Science shall have immediate direction of the publication. The department editors shall be responsible for the approval of papers from their several departments, and all papers offered for publication shall be submitted to such department editors.

The selection for publication from available material shall be determined by the Editorial Board.

Article VIII—Quorum.

A quorum for the transaction of regular business shall consist of at least fifteen members with a representation of at least one-third of the departments included in the society.

Article IX—Amendments.

Amendments to the constitution may be made by the concurrence of three-fourths of the members present at a duly called meeting, notice of such amendment having been given to all members at least one week in advance.

BY-LAWS.

Article I.

The membership fees of the society shall be twenty-five cents per year or one dollar for a period of five years and such fee shall entitle the members to participation in all activities of the society but shall not include the subscription to the Ohio Journal of Science.

Article II.

The subscription price to the Ohio Journal of Science shall be two dollars to non-members, and one dollar and seventy-five cents to members.

Article III.

The fiscal year of the society shall coincide with that of the University—July 1st to June 30th. The publication to be issued during eight months, beginning with November.

Article IV.

Regular meetings shall be held on the second Tuesday evening of the months of October, November, March, April and May. The meeting in May shall be the annual meeting for the election of officers and an editorial board. Other meetings may be called by the Executive Committee, or by the President on petition of five members.

Article V.

The University Instructional Staff shall be understood to include any member of the teaching force.

Article VI.

Amendments to the By-laws may be adopted at any regular meeting by vote of a majority of the members present, notice of proposed amendment having been given at time meeting is called.

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A SURVEY OF THE ZOOCECIDIA ON SPECIES OF HICORIA CAUSED BY PARASITES BELONGING TO THE ERIOPHYIDÆ AND THE ITONIDIDÆ (CECIDOMYIIDÆ).*

BERTRAM W. WELLS.

This paper is primarily an attempt to present adequate descriptions of the types of 30 itonid (cecidomyid) and 2 eriophyid (mite) galls, collected by the writer on hickory leaves. It is believed to contain sufficient new material to warrant its publication in advance of a general survey of N. E. United States zoocecidia, of which it will form a part. The data is based on collections made in Connecticut, Ohio and Kansas, most of the material however, being taken in Ohio.

In addition, those forms (few in number) previously described which have not been seen by the author, have been added, so as to give a character of completeness to the survey of the two groups of galls.

*Contribution from the Botanical Laboratory of the Ohio State University, No. 92.

There are three groups of zoocecidia occurring on hickory trees:

1. Galls formed by species of Eriophyes (Fam. Eriophyidæ of the Acarina or mites), or an allied genus. Only two are known.

2. Galls induced by species of Phylloxera (Aphididæ of the Hemiptera). Pergande† has presented an excellent survey of these insects accompanied by very satisfactory descriptions of the cecidia formed by them.

3. Galls caused by species of Caryomyia (Itonididæ of the Diptera). Possibly other genera may be represented on the hickories, but according to Felt‡ "most of the hickory leaf galls are probably made by species of Caryomyia, though other midges have been reared from these deformities."

The genus Caryomyia, which undoubtedly occupies an important place in relation to the majority of the galls described in the present paper, will be given special consideration. Felt, to whom American cecidology is heavily indebted for his extensive studies of dipterous cecidozoons, presents the following description of the genus Caryomyia in the same citation as that immediately above.

"Allied to Hormomyia, but differing by the thorax not being greatly produced over the head and by the presence of but 14 antennal segments. The males may have the flagellate antennal segments binodose or cylindric and subsessile and invariably with three low, stout circumfili. The antennal segments of the female are cylindric and with two circumfili; palpi tri- or quadri-articulate; wings rather broad, the third vein joining the costa at or near the wing apex; claws simple, the pulvilli well developed. The ovipositor of the female is short and with minute lobes apically. The genus appears to be confined to hickory leaf galls."

Adult insects not technically known are given the old generic name "Cecidomyia."

These galls as well as similar ones on other kinds of plants arise as the result of some stimulus (the nature of which is still not definitely known) applied by the very young larva to the

†Pergande, T. "North American Phylloxerinae affecting Hicoria and other Trees." Proc. Davenport Acad. Sci. 9:185–271, pls. 1–21. 1903.

‡Felt, E. P. "The Identity of the better known Midge Galls." Ottawa Naturalist, Vol. 25, Nos. 11, 12. 1912.

growing tissue of the immature leaf. Nothing has yet been done on the development of the itonid galls of the hickories, but from studies on very similar types we have reason to believe that the ontogeny of the itonid forms is as follows: The egg is probably deposited superficially (for the ovipositor of the female Caryomyia is short) on the under side of the leaflet; on the upper side in a few cases.

Hyperplasia or excessive cell proliferation results (probably not until after the larva has emerged from the egg) forming at first a saucer-shaped structure, then cup-shaped and finally by the ingrowth of the edges, the gall becomes a closed structure enveloping the larva in a chamber. The distal growth, seldom if ever in the hickory forms, proceeds so far as to obliterate the opening which was so prominent in the very immature cup-shape stage. Hence in practically all galls of this type a minute canal or pore can be demonstrated at the distal end. In Küster's* very serviceable classification of abnormal plant parts, these fall under his "umwallungen" cecidia, a term very succinctly describing their mode of development.

Two of the following described galls have been studied histologically by Cook,† *Caryomyia holotricha* O. S. and *C. tubicola* O. S.

Concerning the problem of the distribution of the galls on the different species of hickory, it is still too early to be able to make any positive assertions. In most of the reports the species of tree has not been given. It is very well known that certain species of galls are found on 2 and 3 species of hickory, but whether they are developed on all indiscriminately is not known. *H. cordiformis* seems to bear much fewer species than *H. ovata* or *H. alba*. In the present list, the report of the gall upon a particular species of tree does not at all imply that it does not occur on others.

Having had the opportunity to give attention to gall collecting in three rather widely separate localities, eastern Connecticut, southern and northern Ohio and eastern Kansas, some observations on the geographical distributions of the hickory itonids are here briefly presented.

*Küster, E. Die Gallen der Pflanzen, Leipzig. 1911.

†Cook, Mel T. "Galls and Insects Producing Them." Ohio Nat. 4:140–141. 1904.

It is sometimes stated that the distribution of gall insects is similar to that of their host plants. In certain cases this does not seem to be true. In that of my number 32 first found and described by Sears, no report of this large and striking form has appeared, showing it to occur east of the Allegheny mountain system, a region in which *H. ovata* is abundant. In the cases of my numbers 5, 9, 19 and 31, all heretofore unreported and possessing prominent distinguishing characters, it would seem as though they were somewhat restricted in their distribution, for while comparatively common in Ohio, they are never seen in Connecticut or Kansas, where equally intensive collecting was prosecuted. So few are the students of cecidia and so meager the data in this field, that it is, however, much too early to make positive assertions in matters of geographic distribution.

The data on the galls presented herewith was compiled for the most part at the time of collection; the notes and drawings made from fresh material. For later comparative work, the material was all preserved in formalin, each collection being assigned to a vial.

The writer has refrained from attaching a specific name to his new species of cecidia, a practice very common on the part of European cecidologists. Even though the adult gall has no direct relation to the adult insect, the fact, nevertheless, remains that the specificity of the gall owes its origin to the specificity of the physiological phenomena of the larval insect, and it is this, which in the mind of the writer, gives pre-eminence to the insect. The adult gall and the adult insect can be conceived as arising from the same complex, the larva, the adult insect bearing, however, a more intimate and direct relation to the original source of events than the gall. In many cases the adult insects offer characters, making possible the delimitation of species, with greater exactness, than do the galls. For these reasons new names of cecidia should only appear with adequate descriptions of the cecidozoons.

Though the galls almost uniformly occur on the under side of the leaflet, the drawings have presented them in an inverted position, with the gall uppermost, this being the position in which the galls would be examined. In practically all cases there are two sketches of the type, one showing the exterior aspect of the gall, the other the interior as seen in a vertical, median section. The figure number is in all cases the same as the list number.

The writer wishes to express his appreciation of the hospitality of his friend, J. L. King, who, as assistant entomologist for the Ohio Experiment Station, shared his field laboratory during some of the time in which cecidological collecting was being carried on.

Though the writer has seen (with a few exceptions) the types herewith detailed an amply sufficient number of times to establish them as types, he does not claim infallibility, for the key he has worked out to these types. It is hoped, however, that it, together with the descriptions and illustrations will enable the student of the hickory galls to become better acquainted with the members of the two groups treated.

Britton and Brown's Illustrated Flora Northern U. S. and Canada, (2nd edition), New York, 1913, has been followed in the matter of plant nomenclature.

The following two galls whose makers have been named by Felt have probably not been seen by the writer. Felt's descriptions are given. They are not included in the key.

Caryomyia thompsoni Felt.

"Globose, thin-walled, long haired, melon-shaped, dia. 2–3 mm."

See my number 23.

Caryomyia antennata Felt.

"Globose, thick-walled, yellowish green or brown. Dia. 4–5 mm."

This description as far as it goes, would indicate a similarity to C. persicoides Beut.

Felt, Jour. Econ. Ent. 4:456. 1911.

Key.

The itonid group of galls herewith presented can be distinguished with one exception (No. 33) from the very common Phylloxera galls (Aphididæ) by the fact that the latter forms which are sufficiently small to be comparable in size to the itonids are intercalated in the leaf blade, i. e. the gall extends more or less prominently from both sides of the leaf. The itonids always give the appearance of an appendicular structure attached to the leaf.

1. Gall on nut. Caryomyia nucicola. (3)
1. Gall on leaf. 2.
2. An apparent elongate enlargement of vein. Cecidomyia cynipsea (?) (4).
2. An inrolled leaf edge. (2).
2. Galls arising from intervenal tissue between veins or immediately adjoining veins; radially symmetric structures with principal axis more or less perpendicular to leaf blade. 3.

3. Galls double-chambered as seen in vertical median section. 4.
3. Galls single chambered. 7.
4. Galls definitely depressed. (5).
4. Galls small, sub-globular. (6).
4. Galls definitely conic. 5.
5. Elongate gall with rounded base in definite visible socket. (7).
5. Shorter gall attached by pedicel from rounded base not articulating with definite socket. 6.
6. Proximal chamber of gall, conic. (5).
6. Proximal chamber of gall, depressed. (8).
7. Galls definitely conic; forms having rounded bases, the distal portion is sufficiently drawn out to place the cecidium under this class. 8.
7. Galls spheric, sub-spheric or depressed. 15.
7. Galls sub-cylindric, 2½-3 times as long as wide. 22.
7. Galls obconic, i. e., part projecting from leaf is flat topped, constricted proximally to the pedicel embedded in the leaf. 25.
7. Blister gall, intercalated in the leaflet, projecting on both sides. Cecidomyia? sp. (33).
8. Small irregular, low, masses of tissue always in axils of principal veins of leaflet. Eriophyes sp. (1).
8. Galls definite structures projecting prominently from leaf surface. 9.
9. Conic gall generally with strongly recurved tip appearing as though lying on side, decumbent. (9).
9. Galls erect or tilted, seldom bent over, however, beyond angle of 45. 10.
10. Gall with flattened sides, pyramid-like. (10).
10. Galls with sides flattened. 11.
11. Proximal half of gall conic, never sub-globular. (11).
11. Proximal half sub-globular. 12.
12. Galls smooth. 13.
12. Galls pubescent. 14.
13. Galls large, 4–7 mm. long. (12).
13. Galls small, 1½–4 mm. long. (13).
14. Trichomes very long coarse. (14).
14. Pubescence short, fine. (15.)
15. Galls attached by proximal pedicel embedded in leaf, as seen in a median vertical section.
15. Galls attached by structure extending from leaf into base of gall, which remains on leaf when gall falls. 20.
16. Walls thick, soft. 17.
16. Walls thin, 18.
17. Galls smooth, depressed or with upward flaring walls forming a saucer or cup-shaped structure distal to the chamber. (16).
17. Gall globular, finely pubescent like that of a peach. (17).
18. Surface perfectly smooth, symmetrically sub-spherical galls. 19.
18. Surface minutely shagreen-roughened, gall asymmetric, one side prominently extended laterally. (18).
19. Small galls, 2½ mm. dia., nipple expanded and flattened resembling the end of a bottle. (19).
19. Larger gall, 3–4 mm. dia., nipple short, pointed. (20).
20. Thick-walled, particularly the distal end, covered with heavy tawny pubescence. (21).
20. Thinner walled, pubescence very short, puberulent. 21.
20. Very smooth. (22).
21. Depressed (not over 3 mm. high) with column extending through center of chamber. (23).
21. Globular, 4–5 mm. high. (24).
21. Definitely balloon-shape. (25).
22. Base embedded in socket. 23.
22. Base not embedded in socket. 24.
23. Round-conic at tip. Caryomyia tubicola. (26).
23. Tapering to point, horn-like. (27).

24. Small gall, 2–2½ mm. high, with flaring base, attached by minute pedicel at center. (28).
24. Large gall, 5–6 mm. long, gradually constricted proximally to very narrow neck at point of attachment. (29).
25. Distal face with fovea containing a central nipple. Leaf not projecting on side opposite gall. (30).
25. Distal face with fovea, leading into central pore; no central nipple. Prominent convexity of leaf on side opposite the gall. (31).
25. Distal face flaring out at edge into radiate bracts; these sometimes strongly incurved. (32).

ERIOPHYIDÆ.

1. **Eriophyes?** sp. **Cecidium** nov.

Small galls in the axils of the lateral veins of the leaflets. Above marked by a light colored angular area 1-1½ mm. dia. Below a small mass of tissue (the gall proper) fills the angle, covered by a fine close pubescence. Chamber within of small diameter, irregular in shape. The characteristic mites were definitely observed. They are white in color. On some leaflets every angle made by the mid-vein branching into the lateral ones was occupied by a gall. On *H. cordiformis*, in Athens County, Ohio, August.

Type specimens at Ohio State University.

2. **Eriophyes?** sp.

Leaf edge gall; edge inrolled involving little more than the teeth. Variable in length from .5-2 cm. or longer, 1 mm.-2 mm. thick. Outer surface of affected area finely roughened; color of under side of the leaf. Thompson states that mites live within the fold. His report is the first one on this gall. Species of hickory on which specimens were found not determined.

Thompson, Illus. Cat. Am. Ins. Galls. 1915. p. 57, pl. 10, Fig. 260.

ITONIDIDÆ.

3. **Caryomyia nucicola,** O. S.

"Irregular swelling in the husk produced by the reddish larvæ. Reference to Caryomyia provisional." Felt. "Contain thick walled cells. On Carya (Hicoria) alba." Jarvis.

Osten Sacken, Trans. Am. Ent. Soc. 3:53. 1870.
Felt, Jour. Econ. Ent. 4:457. 1911.
Jarvis, 39th Ann. Rept. Ent. Soc. Ont. 1908. p. 84.

4. **Cecidomyia cynipsea** O. S.

"Rounded, irregular, hard swelling on the under side of the hickory leaf, on the mid-rib near the base of the leaf about

half an inch long. In July, pale yellowish and contained in several small hollows, minute whitish larvæ, with breast bone narrowed anteriorly and ending in a point." Osten Sacken.

This form is so different from the other itonid galls of the hickory that the writer is inclined to place it here tentatively. It is very similar to *Phylloxera caryævenæ* Fitch, with the exception that the hyperplasia extends below the leaf, while in the phylloxera gall it is developed on the upper side. The writer has observed orange colored larvæ in the aphid galls, but they were not definitely determined to be itonid.

Since this type of gall has not since been reported as definitely caused by itonid larvæ, it is barely possible that Osten Sacken described the empty phylloxera gall above mentioned containing inquilinous itonid larvæ. The writer found many of these galls deserted by the aphids in the middle of July and Pergande states that the aphid nymphs begin to leave the galls in July. At this time, these galls are a "pale yellow" color as described for the "cynipsea" gall. The writer's observations were made in southern Ohio, while Osten Sacken's were made in the vicinity of Washington, D. C.

Osten Sacken, Lowe's Monogr. Dipt. N. Am. Pt. 1. p. 193. 1862.

5. **Cecidomyia** sp.

Leaf, under side, double chambered conic or depressed (Fig. 5a) gall. The latter condition is perhaps the more usual. In these forms, the conic tip is sunken in the central fovea, the gall only measuring from 1½-2 mm. vertical diameter. The conic forms are as though the tip was pulled out destroying the fovea. These often measure 5 mm. in height. The width of the galls varies from 3-5 mm. Very light green, or when older yellow to red, surface roughened with low tubercles as seen with lens. Inner chamber sub-conic with short mucronate tip. Walls of both chambers thin and smooth, outer wall slightly sticky. Base of gall flat, arising from a definite pedicel, resting in a cup-like depression, which is formed in a definite hyperplasia intercalated in the leaf. Above, this hyperplasia is evident as a raised circular area, 2½ mm. diameter, in the center of which is a minute light colored papilla.

Rather common on *H. alba*. Collected in Hocking and Athens counties, Ohio.

This double-chambered gall cannot be *Caryomyia inanis* Felt, for it is neither "globose and small." The author describes elsewhere a specimen which fits that description and is very probably produced by the cecidozoon just mentioned. Absolute certainty, it must be remembered, can only be obtained by checking the reared adult insects with the original descriptions.

Sears described this gall from Cedar Point, Ohio, under the name *C. inanis.*

Sears, Ohio Nat. 15:380, pl. 18, Fig. 18. 1914.

6. **Caryomyia inanis** Felt.

"Globose, thin-walled with a false chamber at the apex. Dia. 2-3 mm." Felt.

In my material, the false chamber is large, occupying more than half of the gall. The gall is slightly balloon-shape, 2½ mm. high. Surface perfectly smooth. Collected, Hocking County, Ohio, on H. ovata.

Sears in his "Insect Galls of Cedar Point (Ohio) and Vicinity," described my number 5 under this species.

Felt, Jour. Econ. Ent. 4:456. 1911.
Felt, Bull. Brooklyn Ent. Soc. 8:99. 1913.

7. **Cecidomyia** sp. **Cecidium** nov.

On leaf, under side, elongate-conic constricted somewhat at base so as to resemble a miniature lamp chimney. Arises from saucer-like base. 5 mm. in length. Smooth, greenish-yellow to brown. Two chambered, the larval chamber at the proximal end, sub-spherical with a dia. about ⅓ the length of the gall. The distal false chamber large, the walls becoming thin apically. The partition separating the chambers is firm with a minute perforation at its center. Surface of leaf opposite gall not raised.

Collected in Hocking County, Ohio, on *H. glabra*, July.

Type specimens unaccountably missing. The description is nevertheless presented inasmuch as both it and the drawing were made from fresh material in the field.

8. **Cecidomyia** sp. **Cecidium** nov.

On leaf, under side, a gall similar to 7, perhaps a variety of it, though its prominent and constant differences would indicate a distinct species. Conic with rounded base and truncate tip, 4-6 mm. high, 3-4 mm. broad in widest part. The wall at

the tip thin, splitting into a fimbriate condition. Attached by a minute central pedicel, no trace of a saucer-shaped structure developing around the base. Galls greenish to red and purple tinted. Uniformly being covered with sparsely distributed short hairs. Interiorly two chambered, the larval chamber proximal and occupying nearly one-half of the gall. Walls including the partition comparatively thin. Surface of leaf opposite gall slightly raised with reddish tint.

Collected in Athens County, Ohio, on *H. alba*, August.

Type specimens at Ohio State University.

9. **Cecidomyia** sp. **Cecidium** nov.

On leaf, under side, elongate conic, asymmetric, the axis lying horizontal or parallel with the leaf blade plane. The tip is invariably strongly recurved upward and backward. The side of the proximal part of the gall lying against the leaf is flattened and rests close against the leaf and vein; the galls always spring from the side of a vein. Size variable from 2 mm. in length to 4 mm. this measurement distally not being made to the tip but merely to that part of the recurved terminal portion, farthest from the base. The larger specimens measure 1½–2 mm. in width at the proximal end. Light green to nearly white, or sometimes roseate tinged. Very smooth. Walls thin distally thickening toward the basal end.

Not uncommon on *H. alba* in Hocking County, Ohio, July.

Type specimens at Ohio State University.

A gall, somewhat similar and probably a variety of the above was collected on *H. glabra*, (Fig. 9a.)

Cylindric-conic, sharply bent over against the leaf, attenuate distal part short, not recurved, 3½ mm. long. Smooth, white like ivory. Wall rather thick, hard. Base of gall in shallow saucer-like depression against the vein. Interiorly the distal end is choked with coarse trichomes.

10. **Cecidomyia** sp. **Cecidium** nov.

Leaf, under side, distal ⅔ of gall dome-shaped with 3– many triangular sides, the flaring base resting on the proximal, constricted or saucer-shaped ⅓; 2–3 mm. high, 3–4 mm. wide. Tip attenuate, not sharp pointed, however. Light green to yellowish green, the tip darker, reddish to black. Surface smooth under lens. Larval chamber spherical, surrounded by scler-

enchmya layer. This gall is very distinctive no other forms having the peculiar angular structure which it possesses. Not abundant.

Collected at Gypsum, Ohio, August, on *H. microcarpa*.

Type specimens at Ohio State University.

11. **Cecidomyia** sp. **Cecidium** nov.

On leaf, under side, rather large conic gall, whose distal $\frac{1}{2}$–$\frac{1}{3}$ constitutes a very slender apical process. Through this passes the fine canal leading to the depressed, sub-globular chamber in the proximal part of the gall. The galls are either erect or more generally tilted to one side, always arising from one of the larger veins. 5–8 mm. long, $2\frac{1}{2}$–$3\frac{1}{2}$ mm. wide at base. Outline of the flaring sessile base generally angular. Attenuate distal portion turning dark early. Light greenish yellow to brown when old. Smooth. Walls of chamber thick. A slender probable variety of this is figured in 11a, pl. I.

Collected in Hocking County, Ohio, on *H. alba*. July.

Type specimens at Ohio State University.

12. **Caryomyia caryæcola** O. S.

On leaf, under side, large galls with globular basal part extending into a point distally. Shape suggests that of a Prince Rupert's drop. 4–7 mm. long. Surface very smooth, greenish to reddish tinged. Some show a definite blue color over the attenuate apical end. Walls of medium thickness, very firm. Somewhat similar to *C. sanguinolenta* O. S. but differs from that gall in its larger size and much more attenuate distal end. Common on different hickories.

Osten Sacken, Lowe's Mongr. Dip N. Am. Pt. 1, p. 192. 1862.
Felt, Jour. Econ. Ent. 4:456. 1911.

13. **Caryomyia sanguinolenta** O. S.

On leaf, beneath, stoutly conical, varying in size from $1\frac{1}{2}$ mm. to 4 mm. high. Tip erect or often bent to one side. Smooth, green to purplish-red and finally a brown when old. Attached to smaller veins by short pedicel, hidden from view, however, by the rounded base of the gall. Walls medium in thickness, possessing the rather soft texture of charcoal when dry; brown in color.

This form is often found in enormous numbers on certain trees, bringing about early disintegration of the affected leaves.

The lower leaves are more heavily infested due to the fact that the insects are apt to reach these first in their flight from the ground in the spring.

Osten Sacken, Lowe's Monogr. Dip. N. Am. Pt. 1, p. 192. 1862.
Beutenmuller, Am. Mus. Nat. Hist. Guide Leaflet No. 16, p. 28, Fig. 59. Reprint from Am. Mus. Jour. Vol. 4, 1904.

14. **Cecidomyia** sp. **Cecidium** nov.

Leaf, under side, distal half conic-attenuate from the bulbous or sub-globular proximal half. Covered with long, coarse trichomes, the longest being half the length of the gall. Trichomes brown. Tip of gall generally darker than rest. 3–4 mm. high, 2–3 mm. wide. Cavity sub-spherical somewhat depressed at right angles to axis of gall. Walls relatively thick, especially the proximal part. Apical canal evident in median longitudinal section. Gall attached by short and broad pillar of tissue extending from the leaf into the fleshy base.

Gypsum, Ohio, August, on *H. ovata*.

Type specimens at Ohio State University.

15. **Cecidomyia** sp. **Cecidium** nov.

On leaf, under side, small, conic galls, generally found in pairs closely appressed to each other but not confluent. Distal attenuate $\frac{1}{3}$ rather sharply constricted from the sub-globular $\frac{2}{3}$ of the gall and generally turned to one side. 2 mm. high, $1\frac{1}{2}$–2 mm. broad at base. Yellowish in color, definitely and constantly pubescent. Interiorly the lining of the sub-globular larval chamber is deep blue-black in color. Walls of medium thickness. Comparatively large region of the base involved in the attachment of the gall.

Collected in Hocking County, Ohio, on *H. alba*, July.

Type specimens at Ohio State University.

16. **Cecidomyia** sp.

On leaf, under side, greatly depressed with central, prominent nipple, 3–5 mm. dia. $1\frac{1}{2}$–$2\frac{1}{2}$ mm. thick (vertical dia.) not including nipple. Light green, smooth. Firm fleshy with central sub-spherical larval chamber whose wall is differentiated from the surrounding tissue. Apical canal through nipple evident. This gall first reported and illustrated by Thompson.

Thompson, Illus. Cat. Am. Ins. Galls. 1915. p. 56, pl. 13, Fig. 228.

A most interesting variant of this form is illustrated in Fig. 16a. If it were not for the large number of intermediate forms found, this one would easily be considered distinct. The region of the chamber surrounded by thick walls has been much reduced, so that only a circular area about the upper part of the chamber has the thick wall projecting from it. This new condition results in the formation of a definite saucer-shaped structure on the distal end of the gall. In some specimens the structure was no longer saucer-shape, but by the ingrowth of the edges it was assuming a spherical form, developing a two-chambered gall. It is natural to suspect that this may have been the mode of origin of the four-double-chambered galls described elsewhere in this paper. That, however, is entirely problematic.

17. **Caryomyia periscoides** Beut.

On leaf, underside, generally large, sub-globular galls. Younger ones appear like older, both often being found on same leaflet, 4–7 mm. diameter. Galls covered with a fine short yellowish to reddish pubescence, suggesting the texture of peach "bloom." Walls very thick, firm fleshy, surrounding the central spherical cavity, pierced, however, at the distal end by the fine apical canal. Closely sessile on leaf, generally at side of principal vein. Collected on *H. alba*, *glabra* and *ovata*.

From Felt's short description, *Caryomyia antennata* Felt, must have been taken from a similar gall.

Osten Sacken, Lowe's Mono. Dip. N. Am. Pt. I. p. 193. 1862.
Beutenmuller, Am. Mus. Nat. Hist. Bull. 23:393. 1907.

18. **Cecidomyia** sp.

On leaf, under side, sub-globular (almost uniformly asymmetric in that one side projects laterally so as to present a parabolic outline, rather than a semi-circular one). A short definite nipple terminates the gall. 2–4 mm. diameter. White or light yellow to red. Walls medium in thickness, of a soft, almost fleshy consistency. Exterior surface almost uniformly minutely shagreen-roughened when observed with lens. The constricted base of the gall rests in a shallow saucer-shaped structure.

This gall was described from Connecticut in citation below on *H. ovata*. Rather common in Hocking County, Ohio, on *H. microcarpa*. July, August.

Felt's "Cecidomyia sp. Globose, irregular, ovate, granulate, a slight nipple, dia. 2–3 mm." probably belongs here.

Felt, Jour. Econ. Ent. 4:456. 1911.

Wells, Ohio Nat. 14:291. 1914.

19. **Cecidomyia** sp. **Cecidium** nov.

On leaf, under side, small, smooth, spherical galls, with a peculiar tip shaped like the end of a bottle, arising abruptly from the globular gall, 2–2½ mm. diameter. The gall reminds one of a miniature bomb. Green to yellowish with dark spots over the distal half. Thin-walled. Attached by a minute obconic pedicel. The pupa in these galls is suspended in the upper part of the chamber by a thread passing from each end of the body to the walls of the chamber. The galls drop from the leaves in late July. Not common.

Collected in Hocking County, Ohio, July, on *H. microcarpa*. Type specimens at Ohio State University.

20. **Caryomyia caryæ** O. S.

On leaf, under side, sub-spherical gall with more or less prominent apical nipple. 3–3½ mm. diameter, rarely 4 mm. Light green, turning brown, smooth. In many, very definite meridian-like striations can be observed marking the wall. Wall thin, very fragile and dry. Surface of chamber smooth as though polished. Attached by conic pedicel arising from fovea in base of gall. This pedicel with its pointed end attached to the leaf is surrounded by or rests in a cup-like structure. In this respect the gall differs markedly from No. 22, which it superficially very much resembles.

Fig. 20a is a large specimen showing the peculiar interlocking base exceptionally well developed.

Collected from *H. alba* and *H. ovata*, July and August.

Felt, Jour. Econ. Ent. 4:456. 1911.

21. **Caryomyia holotricha** O. S.

On leaf, under side, large tawny, long-haired galls, distributed singly (Fig. 21) or massed (Fig. 21a) on the leaflet. When massed they form a conspicuous brown, hairy structure, suggesting a huge caterpillar. The isolated galls are subglobular to round-conic with or without a small terminal

nipple. 3–5 mm. vertical diameter, 3–5 mm. wide. Interiorly the chamber of the isolated form is depressed, this fact being associated with that of the thick distal wall. Gall chamber surrounded by definite sclerenchyma layer. Cortical tissue firm. Attached by irregular process from leaf extending into base of gall. In the massed forms, the galls are similar in structure, but are variously shaped, due to mutual pressure, (Fig. 21b). Compactly attached to the common central hyperplasia along the vein, which on the upper side of the leaf is a reddish irregular, low elevation. Some of these masses are as long as 5 cm., possessing a thickness of 10–15 mm.

Common on various hickories, particularly *H. ovata*.

A gall which may eventually prove to be a different species but which here is provisionally classed as a variety of *C. holotricha*, was found in numbers on the leaves of *H. alba*, though it is probably not restricted to this species of hickory. Instead of an apical nipple, it has an apical pit, which is choked with the characteristic brown pubescence of this type of gall. Internally a tuft of coarse brown trichomes extends inwardly from the distal side of the chamber. The chamber occupies the proximal one-half to two-thirds of the gall, the wall over it being uniformly very thick. This type of gall is constant, being collected repeatedly and examined minutely.

Based on Felt's brief description, his *Caryomyia thompsoni* Felt was taken from this gall or one very similar to it.

Closely allied to the above variety is another form, with internal tuft of trichomes, in which the apical nipple is present. The layer of tissue lining the chamber appears very white, due probably to the character of the tissue beneath the superficial nutritive layer. In section the thin white chamber wall is very definitely delimited from the adjoining darker tissues. Many of these conic-sub-spheric galls were 6 mm. in width. Collected on *H. glabra*. Types of this and the above variety are at the Ohio State University.

Osten Sacken, Lowe's Monogr. Dip. N. Am. Pt. I, p. 193. 1862.
Felt, "Hormomyia holotricha" 23rd Rept. Ins. N. Y. 1907. pp. 382, 389.
Felt, "Caryomyia holotricha" Jour. Econ. Ent. 4:456. 1911.

22. **Cecidomyia** sp. **Cecidium** nov.

On leaf, under side, sub-globular with minute apical nipple. Tip of latter truncate with fine pore in center. 3 mm. high, 2½–3 mm. wide. Generally wider through one axis. Smooth;

light greenish yellow. Interiorly a more or less prominent nipple projects inward from the distal end of the chamber, traversed by the apical pore. Toward maturity the interior wall is reddened. Gall attached by a short, cylindric pillar, extending from the leaf into the base of the globular structure. At the end of summer the galls fall from the leaf, leaving this pedicel on the leaf. Galls when found are apt to occur in large numbers, as many as 50–60 commonly being found on a single leaflet.

Collected in Hocking County, Ohio, on *H. microcarpa*, July.

Type specimens at Ohio State University.

23. **Cecidomyia** sp. **Cecidium** nov. (?)

Leaf, under side, depressed (door-knob-shape) closely sessile on leaf attached by a very short stout pedicel. 3–4 mm. wide, 2–2½ mm. high. Greenish to dull brown, covered with short, thin pubescence or smooth. Interiorally from both the proximal and distal sides, truncated, conic processes extend inward, meeting in the center. From the end of the upper one numerous, very coarse trichomes radiate into the gall chamber, which are white at first, turning brown. The central tissue and the walls are of a firm, fleshy character. There is commonly a more or less definite fovea, exteriorly at the distal end.

Collected in southern (Hocking County) and northern (Lake County) Ohio on *H. ovata*.

Thompson briefly describes and illustrates a gall similar to the above which Felt as editor called *Caryomia thomsoni*. The illustration, however, shows the gall not be to Felt's *C. thompsoni* as he has described it, viz., "Globose, with long, erect, reddish, fuscous hairs."

Felt, Bull. Brooklyn Ent. Soc. 8:99. 1913.
Thompson, Illus. Cat. Am. Ins. Galls, p. 56, pl. 12, Fig. 227.

24. **Cecidomyia** sp. **Caryomyia similis** Felt (?)

On leaf, under side, large, globular, 4–5 mm. dia. Light yellow-green to brown, surface puberulent. A minute nipple terminates the gall. Walls thin. Attached by a short pillar, over which the basal part of the sphere fits like a cap. Surface of leaf not noticeably raised on side opposite the gall.

Collected on *H. microcarpa* in Ohio and *H. glabra* in Connecticut.

This gall is very close if not identical with *Caryomyia similis* Felt. It differs from his description in that it is not "depressed."

Felt, Jour. Econ. Ent. 4:456. 1911.
Felt, Bull. Brooklyn Ent. Soc. 8:99. 1913.

25. **Cecidomyia** sp.

On leaf, generally on upper side, balloon-shaped gall, 3–5 mm. high, 3–4 mm. wide. Terminal nipple arising from slight apical depression. Greenish-brown or sometimes varying toward a very dark purplish tinge, its peculiar color being very constant and characteristic. The surface is dotted over with short, swollen glandular hairs. Trichomes sometimes projecting slightly from apical pore. Walls very thin. Galls attached to short, stout process of the leaf, to be seen only in median, vertical section. Surface of leaf on side opposite the gall not raised. Never numerous on leaflet. Closely related, if not identical, with *C. caryae* O. S. See No. 20.

Observed on *H. glabra*, in Hocking County, Ohio, July.

26. **Caryomyia tubicola** O. S.

On leaf, under side, cylindrical with rounded distal end standing erect from the cup-like base embedded in the leaf blade. 4–6 mm. high, generally very close to 5 mm. 1 mm. dia. Body of gall, yellow to brown in color, distal end reddish to brown, at length almost black. Basal cup, greenish yellow to dark purple. Cylindrical part of gall smooth as though polished. Gall attached to the cup only at its central basal part. Before the end of summer the tube-like portion breaks away with its enclosed larva. On the side of the leaf opposite the gall its position is indicated merely by a dark discoloration. Very common on different kinds of hickories.

Osten Sacken, Lowe's Monogr. Dip N. Am. Pt. 1, p. 192, 1862.
Felt, Rept. Ins. N. Y. 1907, pp. 382, 388, pl. 37, Fig. 5.
Felt, "Caryomyia tubicola" Jour. Econ. Ent. 4:456. 1911.

27. **Cecidomyia** sp. **Cecidium** nov.

Leaf, under side, arising from a shallow cup-like structure. Shape of a slender horn, slightly curved, 5–7 mm. long, $1\frac{1}{4}$ mm. wide at base. Light green at base, changing to yellow, the distal $\frac{2}{3}$ of the gall a deep brown. No demonstrable opening at the end. Walls thin. Surface smooth, under lens minute longitudinal striations evident. Very little discoloration on the

upper side of the leaf to mark the location of the gall beneath. Resembles *Caryomyia tubicola* O. S. but is certainly a different species.

Collected in Hocking County, Ohio, July, on *H. alba*.

Type specimens at Ohio State University.

28. **Cecidomyia** sp. **Cecidium** nov.

On leaf, generally upper side, delicate, small, sub-cylindric galls, standing erect, 2–2½ mm. high, less than 1 mm. wide, constricted proximally to the slightly flaring base. Distal end marked off by a circular ridge, in the center of which is a rounded nipple. This latter turns dark early. Gall light green, at length turning brown. Arises from intervenal areas between the smaller veins. On the under side of the leaf the gall above is indicated by a minute dark area. Attached to leaf by minute central pedicel.

Collected in Hocking County, Ohio, on *H. alba* in July.

Type specimens at Ohio State University.

29. **Cecidozoon** (Type undetermined.) **Cecidium** nov.

On leaf, under side, rather large, pouch-like gall (5–6 mm. long) arising from a principal vein. Shaped like a stout gourd, it is bent over nearly recumbent against the blade of the leaf. 2–2½ mm. wide. The proximal end is sharply constricted at the minute point of attachment. The walls when collected were light brown in color, sparsely covered with short white hairs. Walls very thin and when dry brittle. Interior surface smooth. Inconspicuous on the upper side of the leaf, except for the minute pore next the vein. Two specimens from the same leaflet.

This gall differs so markedly from all the other cecidomyidous galls of the hickories, that I am not certain just where to place it. They contained no occupants of any kind.

Collected in Hocking County, Ohio, on *H. glabra*, July.

Type specimens at Ohio State University.

30. **Cecidomyia** sp. **Cecidium** nov.

On leaf, under side, obconic gall resting in firm collar-like base. Somewhat similar to 31, but differs in definite constant characters to make it distinct. Proximal end not rounded but definitely conic, distal broad end with prominent fovea in the

center of which arises a well defined nipple. Dia. across top, 2½ mm., height from leaf surface, 2 mm. Greenish to reddish brown, smooth. No prominence or convexity of leaf surface opposite the gall, a slight discoloration only marking the position of the cecidium.

Collected in Hocking County, Ohio, on *H. microcarpa*, July. Type specimens at Ohio State University.

31. **Cecidomyia** sp. **Cecidium** nov.

On leaf, under side, small, obconic galls which in development appear to burst through the epidermis, for gall is surrounded by the ragged collar-like remnant. The rounded proximal end strongly sunken in the leaf blade which is prominently convex on the opposite side. Distal end truncate with funnel-like depression leading to the rather large apical pore. This latter connects the depressed chamber within with the exterior. Distal broad end 1½ mm. wide. Gall projects from leaf surface 1–1½ mm. Smooth; light greenish-yellow in color. Walls very thick distally, very thin proximally where it is connected to the leaf at the central region. On the upper side of the leaf the low, hemispheric convexity is reddened, particularly toward the periphery. At first it was thought that this gall might be a juvenile form of *H. tubicola*, but later observations have shown it to grow no further in length. It is without doubt distinct and new.

32. **Cecidomyia** sp.

"Leaf-gall on under surface, having the form of a much depressed inverted cone, attached by its apex, and with the free base surrounded by a conspicuous fringe. 3–4 mm. high, 4–5 mm. in diameter. Green to light yellow-green. Huron, July 25. Quite rare and I believe hitherto unreported." Sears.

The author has collected this interesting gall at Gypsum, Ohio, in August. Many of them measured 5 mm., not including the radiate, bract-like processes borne on the flaring rim of the gall. The galls bear an evanescent thin disk of tissue on the distal, central region, which is clear brown in color and bears erect scattered trichomes. The underlying surface of the gall or the outer convex part is perfectly smooth. The origin of the apical, brown disk is problematical; from the material at hand

it appeared as if the rim of the gall had developed by pushing out beneath the original apical tissue. After the disk falls, only a minute dark spot marks the apex of the gall. The surface of the under half of the gall, below the flaring, lacerate rim, is more or less pubescent.

Chamber comparatively large; walls thin.

This very striking gall has thus far only been collected by Mr. Sears and myself, both times in northern Ohio and occurring on *H. ovata*.

Some specimens, all occurring on the same leaf varied in that they were not so depressed (almost sub-hemispheric) and had the rim strongly inturned against the very convex distal half of the gall.

Sears, Ohio Nat. 15:380. 1914.

33. **Cecidomyia?** sp.

On leaf, blister-like, irregularly circular in outline, $2\frac{1}{2}$–$3\frac{1}{2}$ mm. diameter, $\frac{1}{2}$ mm. thick. Extends above and below about equally. Sometimes a slight central nipple is formed below Greenish to brownish with discolored margin.

Collected in Vinton County, Ohio, on *H. cordiformis*.

Probably same as Felt's "Leaf blister gall, irregular, dull greenish or black margined with small nipple. Diameter 3mm."

This type of gall is so different from all the other cecidomyid forms that it is doubtful if it is a member of that group. It may possibly be an immature or small Phylloxera gall. The writer found white larvæ within his specimens, but was unable to determine them as cecidomyid larvæ. This gall is thus introduced here, provisionally.

Felt, Jour. Econ. Ent. 4:456. 1911.

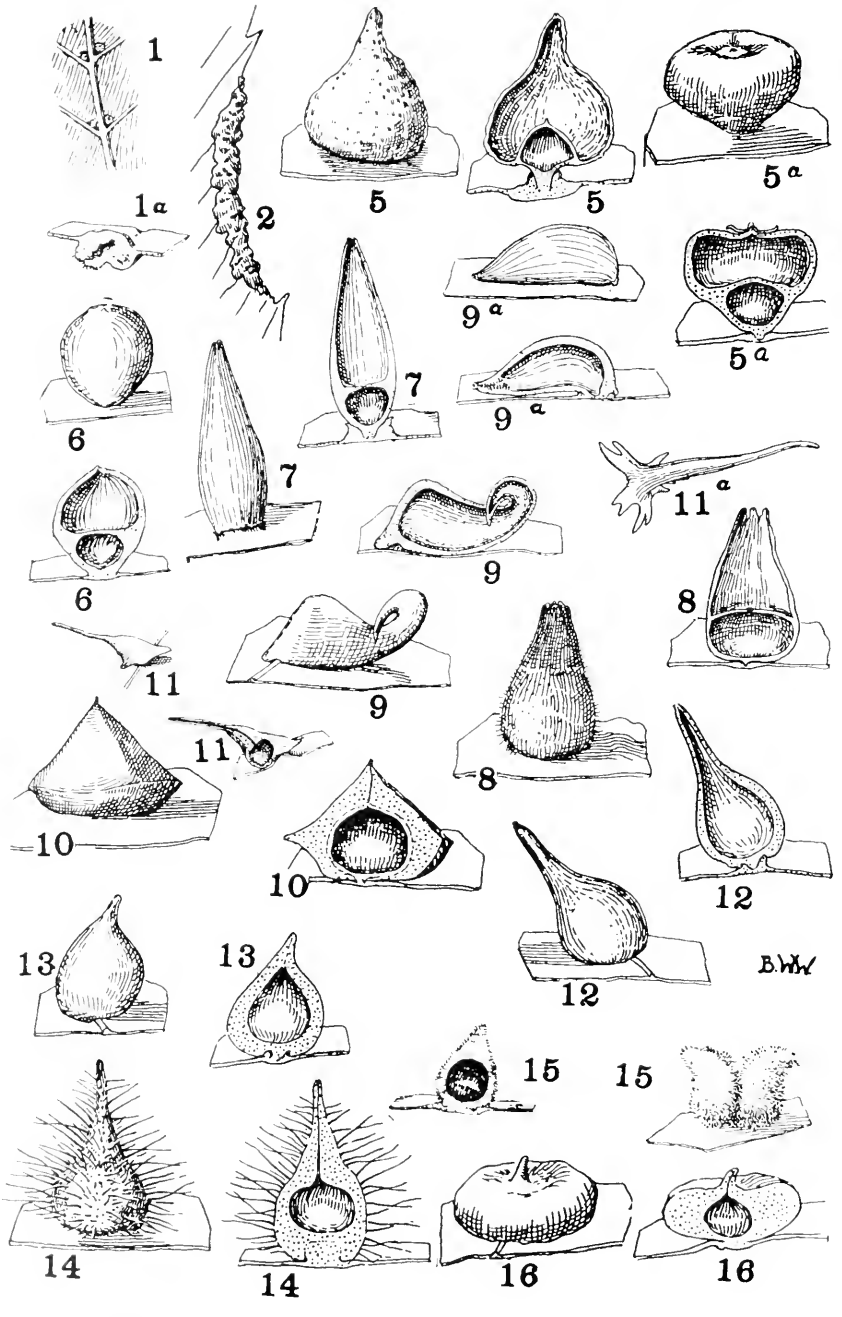
EXPLANATION OF PLATES I AND II.

Plate I.

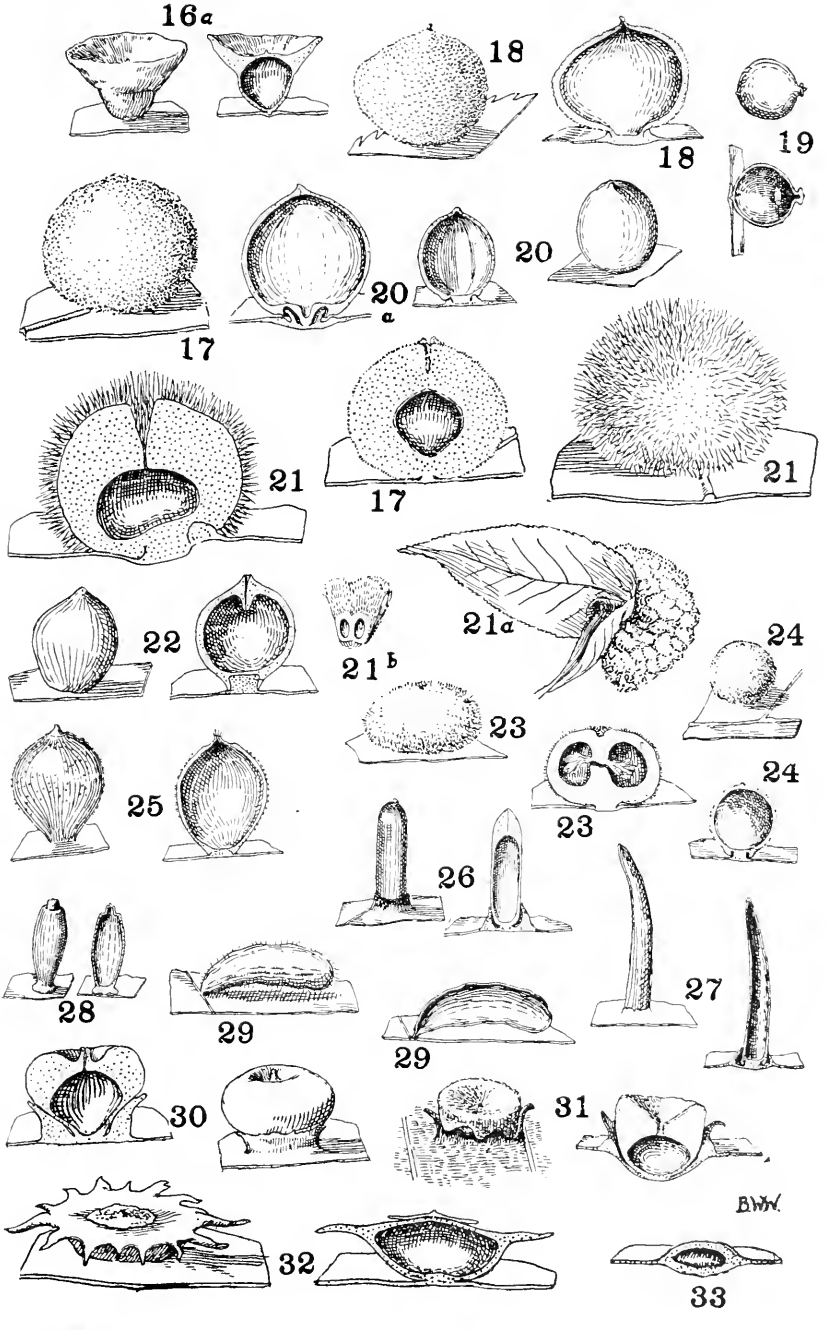
Fig. 1. Mite gall. Eriophyes? sp. × 1⅓.
Fig. 1a. Mite gall. Eriophyes? sp. × 5.
Fig. 2. Mite gall. Eriophyes? sp. × 3.
Fig. 5. Cecidomyia sp. × 4.
Fig. 5a. Cecidomyia sp. Variety. × 4.
Fig. 6. Caryomyia inanis Felt. × 5.
Fig. 7. Cecidomyia sp. New. × 5.
Fig. 8. Cecidomyia sp. New. × 4.
Fig. 9. Cecidomyia sp. New. × 5.
Fig. 9.a Cecidomyia sp. New. Variety. × 5.
Fig. 10. Cecidomyia sp. New. × 5.
Fig. 11. Cecidomyia sp. New. × 1⅓.
Fig. 11a. Cecidomyia sp. New. Variety? × 5.
Fig. 12. Caryomyia caryaecola O. S. × 3.
Fig. 13. Caryomyia sanguinolenta O. S. × 5.
Fig. 14. Cecidomyia sp. New. × 5.
Fig. 15. Cecidomyia sp. New. × 5.
Fig. 16. Cecidomyia sp. × 5.

Plate II.

Fig. 16a. Cecidomyia sp. Variety, new. × 5.
Fig. 17. Caryomyia persicoides. Beut. × 5.
Fig. 18. Cecidomyia sp. × 4.
Fig. 19. Cecidomyia sp. New. × 4.
Fig. 20. Caryomyia caryae O. S. × 5.
Fig. 20a. Caryomyia caryae. Large specimen. × 5.
Fig. 21. Caryomyia holotricha O. S. Isolated specimen. × 5.
Fig. 21a. Caryomyia holotricha O. S. Aggregate condition × ⅔.
Fig. 21b. Caryomyia holotricha O. S. Bilocular unit of aggregate form. ×2.
Fig. 22. Cecidomyia sp. New. × 5.
Fig. 23. Cecidomyia sp. Possibly new. × 5.
Fig. 24. Caryomyia similis Felt (?) × 1.
Fig. 25. Cecidomyia sp. Caryomyia caryae O. S. (?) × 5.
Fig. 26. Caryomyia tubicola O. S. × 3.
Fig. 27. Cecidomyia sp. New. × 3.
Fig. 28. Cecidomyia sp. New. × 5.
Fig. 29. Cecidozoon (undetermined). New. × 3.
Fig. 30. Cecidomyia sp. New. × 7.
Fig. 31. Cecidomyia sp. New. × 6.
Fig. 32. Cecidomyia sp. × 5.
Fig. 33. Cecidomyia ? sp. × 5.



Bertram W. Wells.



Bertram W. Wells.

THE GEOMETRY OF THE TRANSLATED NORMAL CURVE.

CARL J. WEST, Ph. D.

Introduction. In curve tracing the graphic representation is constructed from the equation. Due largely to the requirements of statistics the converse, namely, to find the equation of the curve when the distribution of points is given, has become of interest. This problem is very different from the exercises of analytical geometry in which a given law of distribution of points is to be translated into algebraic language. For the presence in the statistical data of accidental irregularities makes it undesirable as well as practically impossible to obtain a curve passing *through* the points. Instead, a curve is "fitted" to the points, that is, a curve is passed *among* the points in accordance with some generally accepted principal such as that of least squares or the agreement of moments.

Aside from the straight line and the parabolas, the curves proposed by Pearson* have found acceptance. In order to derive curves which can be fitted to widely varying distributions of points, Professor F. Y. Edgeworth† has proposed to modify, to *translate*, the normal probability curve with unit standard deviation,

$$y = \frac{1}{\sqrt{2\pi}} e^{-\frac{t^2}{2}}$$

In this article we shall discuss the geometry of the curves which Edgeworth obtains by this transformation and derive a method for an approximate solution of the two equations, one of the fourth and the other of the sixth degree, which arise in the fitting of a curve of this class.

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* Pearson, Karl:—"Skew Variation in Homogeneous Material;" Phil. Trans. 1895, Vol. CLXXXVI, A, pp. 253 et seq.

"On the Systematic Fitting of Curves to Observations and Measurements," Biometrika, I, pp. 265 et seq. and Biometrika II, pp. 1 et seq.

Elderton:—"Frequency Curves and Correlation," pp. 1-105; C. & E. Layton, 1906.

† Edgerton, F. Y.:—"On the Representation of Statistics by Means of Analytical Geometry," Jour. Roy. Stat. Soc., 1914, Feb., Mar., May, June and July.

In order that the final curve may be written in terms of the co-ordinates x and y the equation of the base or generating normal probability curve is written:

$$z = \frac{1}{\sqrt{2\pi}} e^{-\frac{t^2}{2}}$$

where t denotes abscissas and z ordinates.

Let the abscissas of the transformed curve be functions of the corresponding abscissas of the base curve. Then it may be assumed that x can be developed in powers of t, and hence we may write on omitting fourth and higher powers,

$$x = a(t+\kappa t^2+\lambda t^3),$$

where a, κ and λ are constants to be determined in "fitting" the curve.

Since x denotes the value of a measurement and y the frequency of x, that is, the number of individuals possessing that value of x, the magnitude of an element of area denotes the number of individuals between two values of x. Obviously, therefore, if the transformation is to be of concrete value the magnitude of an element of area must not be altered, though of course the shape will be changed. Hence

$$y\,dx = z\,dt,$$

and

$$y = z\,dt/dx$$

$$= \frac{1}{\sqrt{2\pi}} e^{-\frac{t^2}{2}} \cdot \frac{1}{a(1+2\kappa t+3\lambda t^2)}$$

The formulas of transformation are thus:

$$x = a(t+\kappa t^2+\lambda t^3),$$

$$y = \frac{1}{\sqrt{2\pi}} e^{-\frac{t^2}{2}} \cdot \frac{1}{a(1+2\kappa t+3\lambda t^2)}$$

Maximum and Minimum Points. Since only curves with one maximum point or mode are practically useful it is desirable to determine what values of the constants a, κ and λ give unimodal curves.

We have

$$\frac{dy}{dx} = \frac{dy}{dt} \cdot \frac{dt}{dx} = -\frac{1}{\sqrt{2\pi}} e^{-\frac{t^2}{2}} \cdot \frac{(3\lambda t^3+2\kappa t^2+(1+6\lambda)t+2\kappa)}{a(1+2\kappa t+3\lambda t^2)^2}$$

From the vanishing of the numerator of dy/dx there must result either one or three real modes for each pair of values for λ and κ, that is, for each translated curve. To determine what values of λ and κ give uni-modal curves and what tri-modal it is convenient to consider the plane of λ and κ.

The discriminant of the equation

$$3\lambda t^3+2\kappa t^2+(1+6\lambda)t+2\kappa=0$$

is

$$16\kappa^4-\kappa^2(1+66\lambda+117\lambda^2)+3\lambda(1+6\lambda)^3=0$$

This fourth degree curve crosses the horizontal or λ-axis at $\lambda=0$ and at $\lambda=-1/6$ and when $\lambda=0$ its equation reduces to $16\kappa^4-\kappa^2=0$ or $\kappa=\pm 0$, $\kappa=\pm 1/4$. There is thus contact with the vertical or κ-axis at the origin and that axis is crossed at the points $(0, \pm 1/4)$. At the point $(\lambda=-1/6, \kappa=0)$ there is a cusp with the λ-axis for tangent. The other two intersections with the line $\lambda=-1/6$ are imaginary, indicating the presence of two branches to the curve.

The discriminant of the denominator of dy/dx is the parabola (in λ and κ),

$$\kappa^2-3\lambda=0$$

The evident close geometrical connection between the two discriminants suggests arranging the discriminant of the cubic curve in the following form:

$$(\kappa^2-3\lambda)\ (16\kappa^2-117\lambda^2-18\lambda-1)-27\lambda^3(1-24\lambda)=0$$

From the equation in this, the well known $uv+kws=0$ form, numerous elementary geometrical facts can be derived. The relations to the hyperbola, $16\kappa^2-117\lambda^2-18\lambda-1=0$, and to the parabola, $\kappa^2-3\lambda=0$, premit of the ready plotting of the curve with sufficient accuracy. The general shape of the curve is shown in Figure 1.

It is to be noted that one branch of the curve is within the parabola, almost coinciding with it, while the other crosses it at $\lambda=1/24$. From the original form of this equation it appears that the two branches of this discriminant meet just inside the parabola in the end points with approximate co-ordinates $(0.043, \pm 0.360)$. The geometry of the cusp and end-points on the discriminant curve is suggestive of interesting development in detail.

Values of λ and κ for points on the discriminant give curves with two modes coinciding. All points on one side of the discriminant have three real and distinct modes, and all on the other have one real and two imaginary modes. To determine on which side the points giving three real modes lie we examine a point inside the discriminant. When $\kappa=0$ the modal equation becomes

$$3\lambda t^3+(1+6\lambda)t=0$$

Hence the roots are $t=0$ and $t=\pm\sqrt{-\frac{1+6\lambda}{3\lambda}}$. The quantity under the radical is positive for values of λ between 0 and $-1/6$. Therefore, all points within the discriminant curve yield tri-modal curves and all without uni-modal curves.

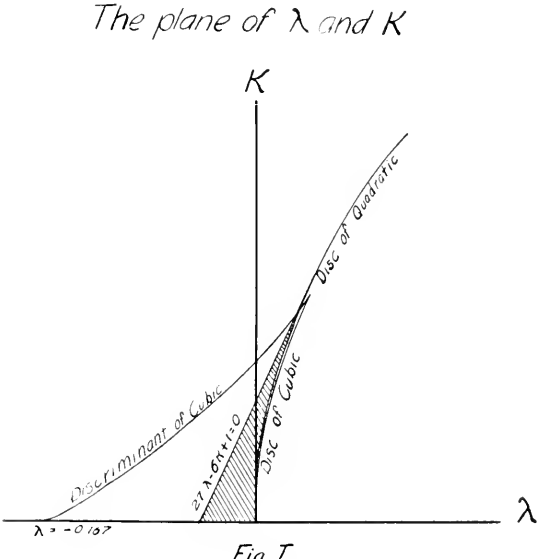


Fig. I

(The horizontal scale is twice the vertical scale)

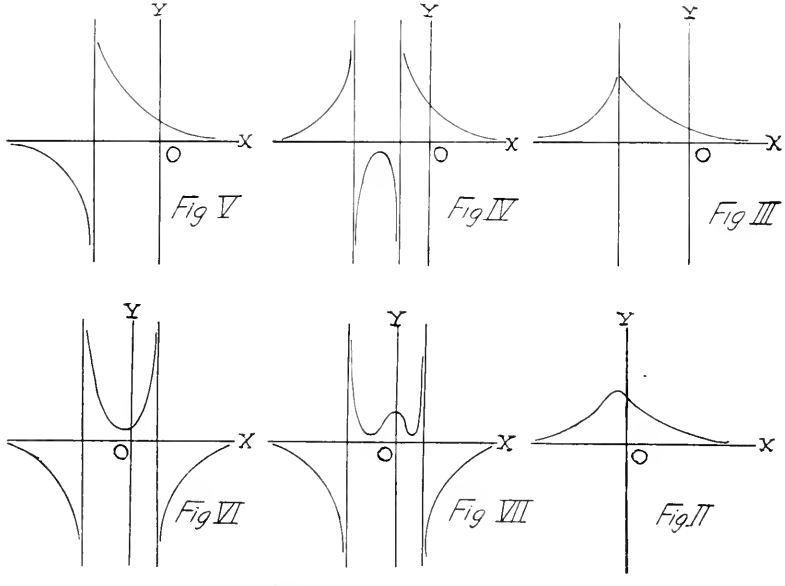
The infinite values of dy/dx arise from zero values of the quadratic, $1+2\kappa t+3\lambda t^2$. The greatest possible number of modes for any one curve is therefore five, three from the cubic and two from the quadratic. Since for infinite values of dy/dx the corresponding ordinates are infinite, it is advisable to study the location of the infinite points of the curve, rather to the neglect of the idea of maximum values at such points.

Infinite Ordinates. The infinite points on a curve are given by the values of t satisfying the equation

$$3\lambda t^2+2\kappa t+1=0$$

Except under certain limited conditions to be determined later a curve with infinite ordinates can not be of great statistical value.

The parabola, $\kappa^2-3\lambda=0$, obtained by equating the discriminant of this quadratic to zero separates the points on the (λ, κ) plane which correspond to curves of *no* infinite points from those corresponding to curves of *two* infinite points.



Types of Curves

Therefore, all pairs of values of λ and κ within the parabola, with the exception of the very narrow region also within the first discriminant curve, give uni-modal curves without infinite ordinates.

Types of Curves. Without entering into detailed proofs we will now investigate the general shape of the curves corresponding to values of λ and κ in each of the distinct regions of the plane of λ and κ.

In the region beneath the parabola and to the right from the shaded area of Fig. I the curve is essentially of the shape shown in Fig. II. This type includes the most common skew curves and hence is of great importance in statistics.

As the point (λ, κ) moves from the λ-axis the crest rises until the parabola is reached when the infinite ordinates appear as two coincident lines, shown in Fig. III.

After the parabola is passed, the infinite ordinates separate and the curve apparently separates into three branches as in Fig. IV.

In crossing the κ-axis to the left one asymptote moves off to infinity giving a curve of the type shown in Fig. V.

Then the asymptote reappears giving a curve of the type shown in Fig. VI.

This general shape is preserved as the point moves toward the λ-axis and when the point reaches the discriminant curve the middle branch is flattened at the minimum point.

For points within the discriminant curve two minimum points appear and the central branch now shows a maximum with a minimum point on either side as in Fig. VII.

The Tri-modal Curves. The curves corresponding to values of (λ, κ) within the discriminant, because of the requirement that an element of area under the translated curve must always be equivalent to the corresponding element under the base or generating curve, can be of statistical value only under the following conditions.

The area between the two ordinates corresponding to $t = \pm 3$ is 0.99998 of the total area under the curve, so that when neither of the minimum points corresponds to points closer than three units to the origin of the base curve the curve may be practically valuable. A moment's consideration will show that the abscissas of the two minimum points must be practically the same as that of the corresponding infinite ordinates. The roots of the quadratic

$$3\lambda t^2 + 2\kappa t + 1 = 0$$

are numerically greater than 3 for all pairs of values of (λ, κ) lying above the line

$$27\lambda - 6\kappa + 1 = 0$$

As statistically promising within the discriminant of the cubic we then have the shaded area of the (λ, κ) plane.

The Origin. The generating curve is the symmetrical normal probability curve with origin at its center. Since $x = 0$ when $t = 0$, the origin of the translated curve coincides with that of the base or generating curve. The translated curve may not be symmetrical so that the mean ordinate may not coincide with the modal ordinate. Because of the relation between correponding areas the ordinate at the origin must continue to divide the area under the curve into equal parts, that is, the origin and median always coincide.

Determination of the Constants. Since the exact position of the median can not ordinarily be determined by inspection or direct computation there are in reality four constants to be determined: the distance between the median and the mean, a, κ and λ.

In determining the constants it is usual to compute the value of the first four moments. The third and fourth moments are extensions of the idea of the well known formulas for the first and second moments. Denoting the moments about the median by μ, we have

$$\mu_1' = \frac{1}{N}\int_{-\infty}^{+\infty} xydx$$

$$\mu_2' = \frac{1}{N}\int_{-\infty}^{+\infty} x^2ydx$$

$$\mu_3' = \frac{1}{N}\int_{-\infty}^{+\infty} x^3ydx$$

$$\mu_4' = \frac{1}{N}\int_{-\infty}^{+\infty} x^4ydx$$

where N is the total area under the curve.

The values of the μ's are computed from the data* and equated to the corresponding integrals which of course involve the four constants. In this way four equations are obtained from which the values of the constants may be determined. Since it is our present object to discuss the solution only of these equations, merely the principal results will be given.

*Elderton, l. c.

The general form for the moments about the median of the area under the translated curve is

$$\mu_n' = \frac{1}{N}\int_{-\infty}^{+\infty} x^n y\,dx$$

$$= \frac{1}{\sqrt{2\pi}\,N}\int_{-\infty}^{+\infty} \frac{a^n(t+\kappa t^2+\lambda t^3)^n}{a(1+2\kappa t+3\lambda t^2)}\, e^{-\frac{t^2}{2}}\, a(1+2\kappa t+3\lambda t^2)\,dt$$

$$= \frac{1}{\sqrt{2\pi}\,N}\int_{-\infty}^{+\infty} a^n(t+\kappa t^2+\lambda t^3)^n e^{-\frac{t^2}{2}}\,dt$$

On applying the two well known formulas:

$$\int_{-\infty}^{+\infty} x^{2n+1}e^{-x^2}dx = 0$$

$$\int_{-\infty}^{+\infty} x^{2n+2}e^{-x^2}dx = \frac{2n+1}{2}\int_{-\infty}^{+\infty} x^{2n}e^{-x^2}dx,$$

the determination of μ_1', μ_2', μ_3' and μ_4' is reduced to a matter of algebraic detail. Then on transferring to the arithmetic mean as origin the values of μ_2, μ_3, and μ_4 can be determined in terms of a, κ and λ. It is most convenient however, to make use of the quantities $\beta_1 = \mu_3^2/\mu_2^3$ and $\beta_2 = \mu_4/\mu_2^2$ or rather $\beta = \beta_1/S$ and $\epsilon = (\beta_2 - 3)/12$ and express the constants in terms of these quantities. It is to be noted that both ϵ and β are zero for a normal distribution, that is, for $\lambda = \kappa = 0$.

Omitting the detailed reduction* which is straightforward and direct, we have

$$(1)\quad \mu' = a\kappa$$

$$(2)\quad \mu_2 = a^2(1+6x+15x^2+2\kappa^2)$$

$$(3)\quad \beta = \frac{2\kappa^2(2\kappa^2+Q)^2}{(2\kappa^2+R)^3}$$

$$(4)\quad \epsilon = \frac{4\kappa^4+4\kappa^2 S+T}{(2\kappa^2+R)^2}$$

where the symbols, S, R, Q and T are defined as follows:

$$S = 1+18\lambda+90\lambda^2,$$
$$R = 1+6\lambda+15\lambda^2,$$
$$Q = 1.5+18\lambda+135/2\lambda^2,$$
$$T = 2\lambda+36\lambda^2+270\lambda^3+810\lambda^4.$$

* Compare Edgeworth, "A Method of Representing Statistics by Analytical Geometry," Proceedings Fifth International Congress of Mathematicians, Cambridge, 1912.

Obviously no algebaric solution can be obtained from equations (3) and (4) for κ and λ in terms of the computed values β and ϵ, and hence a resort to tables is necessary. The values of β and ϵ for values of κ from 0 to 0.0335 and of λ from −0.040 to +0.100 have been computed.* The process of determining the constants of the translated normal curve consists first in computing β and ϵ from the given data, and then in entering the table and interpolating for the corresponding values of κ and λ.† On substituting these values in (2) the value of a can be found and thence on multiplying a by κ the position of the median of the distribution is obtained.

The sign of κ is determined by the sign of the third moment about the mean μ_3, that is, by the direction of the skewness or asymetry. For positive skewness the mean must lie to the right of the median and hence μ_1', the first moment about the mean, must be positive which necessitates a positive sign for κ. Therefore, the sign of κ is the same as that of the skewness.

To fit a curve to the given data, after the constants have been determined it is necessary to find, by solving a cubic equation for each value, the values of t corresponding to the x's of the respective classes. The cubic is

$$a\lambda t^3 + a\kappa t^2 + at - x = 0$$

Any of the various methods of approximating to the solution of a cubic may be used in solving these equations.

The area of each class can now be obtained by computing the corresponding areas under the standard normal curve from a table of the probability integral.

The Method of Interpolation. The actual fitting of the curve can now be readily accomplished.‡ The distinctively geometrical operation is the interpolation for the values of λ and κ for a given pair of values of β and ϵ.

Within the limits of the table§ the curves resulting from the assignment of a constant value to β are practically straight

*Only a part of the original table appears in the accompanying table. The original values were computed to four places of decimals, but three place numbers are suffieient to illustrate the method of approximating to the solution.

†Compare "Tables for Statisticians and Biometricians," Cambridge University Press, 1914.

‡For the statistical details see Elderton, l. c.

§As may be seen on examining the Table.

lines, $\beta = 0$ is the λ—axis; $\beta = 1$ is a line parallel to the λ—axis. Hence we may safely assume that the variation from one column to the next and from one line to the next is linear for values of β. That is, ordinary first difference interpolation methods are applicable.

As regards the system of ϵ curves we have for instance $\epsilon = .128$ at $(\lambda = .050, \kappa = 0)$; again, at approximately $(.045, .060)$ and $(.40, .085)$. We are therefore warranted in assuming the applicability of first difference methods to interpolation between the ϵ curves.

As an illustration let us find the values of λ and κ for $\epsilon = 0.112$ and $\beta = 0.044$. On inspection of the table it is seen that λ lies between 0.30 and .035 and κ between .090 and .095. When $\kappa = .090$, $\lambda = .033$ for $\epsilon = .112$. When $\kappa = .095$, $\lambda = .031$ for $\epsilon = .112$. For $\beta = .042$ and $\kappa = .090$, $\lambda = .033$ and for $\beta = .046$ and $\kappa = .095$, $\lambda = .031$, $\epsilon = .112$ in each case. Hence, to first differences, $\lambda = .032$ and $\kappa = .093$ for $\epsilon = .112$ and $\beta = .044$. For interpolation in parts of the table showing more rapid variations appropriate methods will suggest themselves.

Taken geometrically the table represents two distinct systems of curves, with each curve of one system intersecting all the curves of the other system. Therefore, a pair of values for λ and κ can always be found for values of ϵ and β within the range of the table.

Department of Mathematics, Ohio State University.

TABLE OF ϵ AND β.

(ϵ is the first and β the second number of each pair.)

λ

κ	-040	-035	-030	-025	-020	-015	-010	-005	000	005	010	015	020	025	030	035	040	045	050
000	-061	-056	-050	-043	-035	-027	-019	-010	000	010	021	033	045	057	071	084	098	113	128
	000	000	000	000	000	000	000	000	000	000	000	000	000	000	000	000	000	000	000
005		-055	-049	-042	-035	-027	-019	-010	000	010	021	033	045	057	071	084	098	113	128
		000	000	000	000	000	000	000	000	000	000	000	000	000	000	000	000	000	000
010		-055	-049	-042	-035	-027	-018	-010	000	011	022	033	045	058	071	085	099	113	128
		000	000	000	000	000	000	000	001	001	001	001	001	001	001	001	001	001	001
015			-049	-042	-035	-027	-018	-009	001	011	022	034	046	058	071	085	099	114	129
			001	001	001	001	001	001	001	001	001	001	001	001	001	001	001	001	001
020			-048	-041	-034	-026	-017	-008	002	012	023	034	046	059	072	086	100	115	130
			001	002	002	002	002	002	002	002	002	002	002	002	002	002	002	002	002
025			-047	-040	-033	-025	-016	-007	003	013	024	035	047	060	073	087	101	116	131
			002	002	002	003	003	003	003	003	003	003	003	003	003	003	003	003	003
030			-046	-039	-032	-024	-015	-006	004	014	025	036	049	061	074	088	102	117	132
			003	003	004	004	004	004	004	004	004	004	005	005	005	005	005	005	005
035			-045	-038	-031	-023	-014	-005	005	015	026	038	050	063	076	089	104	118	133
			004	005	005	005	005	005	006	006	006	006	006	006	006	007	007	007	007
040				-037	-030	-022	-013	-004	006	017	028	039	052	064	077	091	105	120	135
				006	006	007	007	007	007	007	008	008	008	008	008	008	009	009	009
045				-036	-028	-020	-011	-002	008	019	030	041	053	066	079	093	107	122	137
				008	008	008	009	009	009	009	010	010	010	010	011	011	011	011	011
050				-034	-026	-018	-009	-000	010	021	032	043	055	068	081	095	109	124	139
				009	010	010	011	011	011	012	012	012	012	013	013	013	013	014	014
055				-032	-024	-016	-007	002	012	023	034	045	057	070	083	097	111	126	141
				011	012	012	013	013	013	014	014	015	015	015	016	016	016	016	017
060					-022	-014	-005	004	014	025	036	048	060	073	086	100	114	129	144
					014	015	015	016	016	017	017	017	018	018	019	019	019	019	020
065					-020	-012	-003	006	017	028	039	050	062	075	089	102	116	131	146
					016	017	018	018	019	019	020	020	021	021	022	022	022	023	023
070					-018	-009	000	009	019	030	041	053	065	078	091	105	119	134	149
					019	020	020	021	022	022	023	024	024	025	026	026	026	026	027
075					-015	-007	002	012	022	033	044	056	068	081	094	108	122	137	152
					022	023	023	024	025	026	026	027	028	028	029	029	030	030	031
080					-013	-004	005	015	025	036	047	059	071	084	097	111	125	140	155
					025	026	026	027	028	029	030	031	031	032	033	033	034	034	035
085						-001	008	018	028	039	050	062	075	088	101	115	129	144	159
						029	030	031	032	033	034	034	035	036	037	037	038	039	039
090						002	011	021	032	043	054	066	079	092	105	119	133	148	163
						032	033	034	036	037	038	039	039	040	041	042	042	043	044
095						005	015	025	035	046	058	070	083	096	109	123	137	152	167
						036	037	038	039	041	042	043	044	045	046	046	047	048	049
100						009	018	028	039	050	062	074	087	100	113	127	141	156	171
						039	041	042	044	045	046	047	048	049	050	051	052	053	054

A PRELIMINARY LIST OF THE JASSOIDEA OF MISSOURI WITH NOTES ON SPECIES.

By Edmund H. Gibson and Eric S. Cogan, U. S. Bureau of Entomology.

The following preliminary list of the Jassoidea of Missouri is mainly the result of collections and notes made by the authors during the summer months of 1915. On account of the lack of records for this state the authors were prompted to undertake such a survey. As far as possible collections were made so as to embrace all conditions in different sections, giving some attention to ecological relations. The list comprises some 98 species.

BYTHOSCOPIDAE.

Macropsis apicalis Osb. & Ball. A few specimens swept from weeds at Charleston, Mo., during the late summer.

Bythoscopus distinctus VanDuzee. Found in great numbers on willows in northern Missouri.

Pediopsis viridis Fitch. Not common. Taken from willows near drainage canals in southeast Missouri. Somewhat more numerous in northern part of the state.

Idiocerus nervatus VanDuzee. The only species taken from willows about Chillicothe.

Idiocerus verticis Say. Listed by VanDuzee as occurring in the state.

Idiocerus crataegi VanDuzee. Swept from grasses at Chillicothe.

Idiocerus snowi Gill & Baker. Recorded from Lutesville and Charleston. Feeding on millet and grasses. Nymphs numerous during August.

Agallia sanguinolenta Prov. Most plentiful in southern part of state. A decided pest of clover and alfalfa. Other food plants include wheat and several weeds. Adults abroad in fields all seasons of the year. Abundant in northern Arkansas.

Agallia constricta VanDuzee. One of the earliest jassids to appear in the spring. Most numerous on grains. Attacks wheat, rye, oats, alfalfa and grass. Abundant in southern counties.

Agallia uhleri VanDuzee. Not very numerous. Occurring principally near swamps along the Mississippi River. Also collected from clover fields.

Agallia novella Say. Rather uncommon. Taken only in southern half of state. Adults collected from alfalfa and from weeds growing in marshes and bogs.

Agallia 4-punctata Prov. Clover and alfalfa are among its food plants. Most abundant in southern counties.

Agallia gillettei O. & B. Quite rare. A few adults taken at Charleston.

TETTIGONIDELLIAE.

Oncometopia undata Fabr. Occurs throughout the state, but not abundant. Swept from grass, weeds and a number of shrubs.

Oncometopia costalis Fabr. Occasional specimens taken throughout southern part of state. Also recorded in the collection of the Experiment Station at Columbia.

Homalodisca coagulata Say. Occasional specimens taken from cotton and cowpeas. Not abundant.

Aulacizes irrorata Fabr. Recorded from the collection of the Experiment Station at Columbia.

Kolla bifida Say. Swept from weeds in marshy lands and from willows and several shrubs. Recorded only in Mississippi County.

Kolla geometrica Sign. Not common. Recorded from Springfield on grass.

Kolla tripunctata Fitch. Mentioned in VanDuzee's Catalogue of Described Jassoidea of N. A. as occurring in Missouri.

Tettigoniella gothica Sign. Only one specimen taken. From grass at Lutesville, August 13.

Tettigoniella occatoria Say. Common in eastern part of state. Feeds on clover and weeds.

Tettigoniella hartii Wood. Quite numerous throughout the state during the late summer. Captured only from meadows and grass lands.

Tettigoniella hieroglyphica Say. Rather common in all parts of the state. Known to feed on clover and several weeds.

Tettigoniella hieorglyphica Say. var. hieroglyphica Say. One adult captured from grass at Rolla, September 21, by Mr. Geo. W. Barber.

Tettigoniella hieroglyphica Say. var. uhleri Ball. Rather common in eastern half of state. Taken from clover and weeds.

Tettigoniella hieroglyphica Say. var. confluens Uhler. Taken with the above variety.

Diedrocephala coccinea Forst. Very generally distributed. Common but not in great numbers. Injurious to many ornamental plants in the Missouri Botanical Gardens at St. Louis. Nymphal cast shins observed on leaves of Magnolia and American Holly. Adults taken from several kinds of trees near swamps along the Mississippi River.

Diedrocephala versuta Say. Very abundant in central and southern Missouri. Adults first observed in June. All stages abroad in fields from July to November. Injurious to cowpeas in Southeast Missouri. Food plants include alfalfa, clover, sunflower, grasses, and many weeds. Common on several ornamental plants and shrubs in the Missouri Botanical Gardens at St. Louis during September.

Draeculacephala reticulata Sign. Rather common at Charleston and Sikeston during July and August and September, on corn, alfalfa and grasses. Taken at Chillicothe, Sept. 6, Stanberry, Sept. 7. The last two records extend the distribution of this jassid to north of the Missouri River, a fact which is interesting in view of the distribution recorded by Prof. Osborn in Bull. 108. Bur. of Ent.

Draeculacephala angulifera Walker. Quite common on grass at Charleston.

Draeculacephala mollipes Say. Abundant throughout the state. All stages present from April to November. Of great economic importance. A decided pest to young grains and grasses. Known to feed on an innumerable list of plants and shrubs, field crops, and ornamentals. Adults migrate in large numbers. About the most common jassid in Missouri.

Draeculacephala noveboracensis Fitch. Taken on grass at Charleston.

Helochara communis Fitch. Swept from wheat on many warm, sunny days during the winter. In July collected from alfalfa. Recorded only from Mississippi County.

Gypona 8-lineata Say. Occurs throughout the state. Has special liking for shady and damp places. Appears to be essentially a grass feeder.

Gypona flavilineata Fitch. Swept from grass lands at Chillicothe.
Gypona cana Burm. Taken with G. flavilineata.
Gypona pectoralis Spangb. Taken with G. flavilineata.

JASSIDAE.

Xestocephalus pulicarius VanDuzee. One specimen of this form taken at an electric light at Charleston, July 28.

Xestocephalus tesselatus VanDuzee. Collected from elm leaves at Charleston. Quite rare.

Hecalus lineatus Uhler. Not common. Nymphs more numerous than adults during August. Swept from rank growing grasses near the Mississippi River at Hannibal.

Parabolocratus viridis Uhler. Recorded from Springfield, Columbia, Chillicothe, and Charleston. Observed feeding on grass, sweet clover and sorghum.

Platymetopius acutus Say. Only one adult collected. Swept from weeds near a bog at Charleston, July 28.

Platymetopius frontalis VanDuzee. Very common throughout the state. Attacks clover, alfalfa, and grasses. Also taken from woody shrubs.

Deltocephalus nigrifrons Forbes. Generally distributed in all sections of the state. Very abundant during October. Known to feed upon clover, alfalfa, wheat, many grasses including blue grass, and several weeds. Attracted to lights at night.

Deltocephalus weedi VanDuzee. Quite common on weeds along roadsides and shady places. Collected at Lutesville and Charleston during the late summer.

Deltocephalus flavicosta Stal. Quite abundant during middle and late summer, principally in southern part of state. Swept from native grasses and weeds. Occasional specimens taken from wheat.

Deltocephalus sayi Fitch. Recorded from grass lands in North western parts of state in September. Quite common in blue grass.

Deltocephalus inimicus Say. Common in all parts of the state. All stages taken from May to November. Food plants include wheat, oats, alfalfa, clover, cowpeas, timothy, blue grass, other native grasses, and weeds.

Deltocephalus albidus Osb. & Ball. Recorded from the collection of the Experiment Station at Columbia.

Deltocephalus obtectus Osb. & Ball. Quite scarce. Recorded only from Mississippi County. Near swamps.

Deltocephalus misellus Ball. Captured but one adult, in a corn field near Mississippi River at West Quincy.

Deltocephalus productus Walker. Rather scarce. Swept from clover and weeds at Stanberry.

Deltocephalus debilis Uhler. Quite common on grasses in rye and wheat stubble fields about Hannibal and West Quincy.

Athysanus exitiosus Uhler. Occurs throughout the state. With the exception of Draeculacephala mollipes it is the most common jassid of northwestern Missouri. Adults present at all seasons of the year. Food plants include wheat, oats, corn, alfalfa, grasses, and weeds.

Athysanus bicolor VanDuzee. Numerous in southern part of state, especially in low or bottom lands. Feeds upon many weeds, grasses and alfalfa.

Athysanus obtutus VanDuzee. Not common. A few adults taken from sweeping wheat fields in the early spring. Recorded only from Mississippi County.

Athysanus plutonius Uhler. Rather rare. Occasional specimens swept from wheat in Scott and Mississippi Counties.

Athysanus curtisi Fitch. Only one adult captured sweeping weeds at Hannibal.

Eutettix clarivida VanDuzee. Recorded from Lutesville and Charleston, from millet and grasses. Nymphs numerous during August.

Eutettix osborni Ball. Collected by Geo. W. Barber at Poplar Bluff, from White Aster, used in ornamental plantings.

Eutettix seminuda Say. Rather numerous but not abundant. Occurring in all parts of the state. Collected principally from weeds and woody shrubs near swamps. Also from grape vines.

Eutettix strobi Fitch. Only one adult captured. Feeding on a leaf of a willow tree growing in a swamp.

Phlepsius apertus VanDuzee. Very common throughout the state, especially in the southeast section. Occurs in great numbers on alfalfa and clover upon which crops they must be considered a pest. Also recorded from grasses and weeds. Most abundant during July and August.

Phlepsius irroratus Say. Very common and generally distributed throughout the state. Of economic importance, attacking alfalfa, clover, cowpeas, corn, wheat, oats, grape, many grasses, and weeds.

Phlepsius cinereus VanDuzee. Recorded only from Mississippi County. Most numerous in early summer. Often taken at lights.

Phlepsius pallidus VanDuzee. Collected at lights during summer months. Generally distributed but not abundant.

Phlepsius superbus Uhler. Not abundant. Occasional specimens captured in Mississippi County.

Scaphoideus sanctus Say. Occasional specimens taken in southern part of state.

Scaphoideus productus Osborn. One adult collected at Rodney, August 25.

Scaphoideus scalaris VanDuzee. Quite common. Recorded from Springfield and Hannibal. Taken only from weeds.

Scaphoideus jucundus Uhler. Occurs on rank weeds and willows. Only record is from Stanberry.

Scaphoideus immistus Say. Swept from woody shrubs and rank grasses about Charleston.

Scaphoideus immistus Say. var. minor Osborn. One adult taken at Charleston.

Thamnotettix clitellarius Say. An occasional adult taken in sweepings from grasses and weeds in southeast Missouri. Also taken from grape at Columbia.

Chlorotettix viridius VanDuzee. A few adults taken during the summer from grasses and weeds growing in low and swampy lands. Recorded from Pattonsburg and Charleston.

Chlorotettix unicolor Fitch. Rather common in central and northern parts of state. Collected from willows growing in lowlands.

Chlorotettix tergatus Fitch. One adult collected at Charleston, September 2.

Chlorotettix necopina VanDuzee. Only record is from Charleston where adults were swept from weeds growing in marshy places.

Chlorotettix galbanata VanDuzee. Quite rare. Occasional specimens taken from weeds growing along roadsides in Mississippi County.

Jassus olitorius Say. Not common. A few adults taken in southeast Missouri. Observed them feeding upon alfalfa.

Balclutha punctatus Thunbg. Only record of occurrence is from Pattonsburg.

Gnathodus impictus VanDuzee. Not numerous. Observed feeding on grasses and several weeds at Charleston during May.

Cicadula 6-notata Fall. Occurs in all sections of the state, most abundant in northeast. Known to feed upon wheat, oats, and grasses. Especially numerous during October.

Empoasca mali LeB. One of the most common and probably the most injurious leafhopper. Feeds on a great variety of plants, shrubs and trees. A pest of field crops, nursery stock, and orchards. Especially abundant during the summer of 1915 on alfalfa and clover. In early spring adults have been observed feeding on wheat, rye and native grasses. Exhibits great adaptability to changes of climate and host plants.

Empoasca smaragdula Fall. Listed by Gillette as occurring in the state.

Empoasca radiata Gillette. Swept from willows growing in the Missouri Botanical Gardens at St. Louis.

Dicraneura abnormis Walsh. Not common. Few specimens collected from blue grass and around lights at night at Chillicothe, during September.

Typhlocyba illinoiensis Gillette. Noted feeding on rose leaves in the Missouri Botanical Gardens at St. Louis.

Typhlocyba obliqua Say. Very abundant on many weeds at Springfield during August.

Typhlocyba trifasciata Say. Listed by Gillette as occurring in the state.

Typhlocyba tricincta Fitch. Abundant on several ornamental bushes in Missouri Botanical Gardens at St. Louis. Adults exceedingly quick of movement. Also collected at Pattonsburg and Columbia.

Typhlocyba comes Say. Abundant throughout the state. A severe pest of grapes, especially in southeast Missouri. Feeds on a number of weeds. Attracted to lights at night in considerable numbers.

Typhlocyba comes Say. var. vitis Harris. Occurring on ornamental shrubs, including rose, in the Missouri Botanical Gardens at St. Louis.

Typhlocyba comes Say. var. scutelleris Gillette. Very common on Sycamore in all stages, and frequently causing severe infestations. Nymphs and adults feed on under side of leaves resulting in small whitish brown spots. Occurs in all parts of Missouri.

Typhlocyba comes Say. var. basilaris Say. One adult captured by Geo. W. Barber at Poplar Bluff, September 4, from white aster.

Typhlocyba comes Say. var. ziczac Walsh. Collected from rose bushes in the Missouri Botanical Gardens at St. Louis.

Typhlocyba vulnerata Fitch. Rather numerous on several ornamental shrubs growing in the Missouri Botanical Gardens. Feeds on under side of leaves.

NEWS AND NOTES.

The Twenty-fifth Annual Meeting of the Ohio Academy of Science was held at the Ohio State University, at Columbus, on November 26th and 27th. A special program was given in commemoration of the Quarter Centennial Anniversary.

The American Association for the Advancement of Science will hold its Annual Meeting on the Ohio State University Campus, at Columbus, December 27th, 1915 to January 1st, 1916. A large attendance is expected and arrangements have been completed to make the meeting one of unusual interest.

At the November meeting of the Biological Club, the following officers were elected for the ensuing year: President, Dr. F. H. Krecker of the Department of Zoology and Entomology; Vice President, Miss Clara G. Mark, of the Department of Geology; Secretary and Treasurer, Mr. Rollo C. Baker, of the Department of Anatomy.

The following officers were named by the Ohio State University Scientific Society for the year: President, F. C. Blake, Department of Physics; Vice President, Jas. R. Withrow, Department of Chemistry; Secretary, R. J. Seymour, Department of Physiology; Treasurer, C. J. West, Department of Mathematics. These officers constitute an executive committee which will arrange programs for the regular meetings of the society, the first of which will occur during January.

An interesting event occurring during the recent meeting of the Ohio Academy of Science was the short talk given by Dr. T. C. Mendenhall to the New York and San Francisco alumni of the Ohio State University by means of the trans-continental telephone. Dr. Mendenhall, while a member of the University faculty, established the first telephone to be used in central Ohio, a line from his University office to his residence, and he expressed himself as greatly pleased at the opportunity accorded him to speak to his former students over a line extending across the continent.

The Ohio Academy of Science at its November meeting voted to change the date of its annual session to a time corresponding to the Easter recess. The exact time of the meeting is to be determined by the executive committee, the Academy voting to have the next meeting occur in the spring of 1916.

Established last Spring, the latest honorary society, Phi Sigma, a student organization open only to students having completed an amount of biological work equivalent to a minor, has awakened interest in the universities of other states. Inquiries concerning the possibility of establishing other chapters at distant institutions have been received by the parent chapter at Ohio State University and it is probable that such chapters will be formed during the present year. Phi Sigma hopes to publish a biological quarterly in the near future.

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NOTES ON THE ELECTRICAL BEHAVIOR OF PORCELAIN AND GLASS AT MODERATELY HIGH TEMPERATURES.

ROBT. F. EARHART.

(Paper read at the Oberlin meeting of the Ohio Academy, Nov., 1913.)

The experiments described were carried on by the author during the fall and winter of 1912-1913.

They were suggested by an earlier experiment performed several years ago on the conduction of electricity through gases at high temperatures. During these earlier experiments certain gases were contained in glazed porcelain vessels and subjected to temperatures of 500° and 600° C. It was noted at that time incidentally that when the porcelain was subject to a high e. m. f., a current of some magnitude traversed the porcelain and that while the e. m. f. was steady the current through the porcelain steadily decreased with time.

Soon after this I suggested an experiment to Mr. Henderson, a student in Ceramics in the Ohio State University, and Mr. Geo. Weimar of the Electrical Engineering Department, which they undertook as a joint thesis. Their experiment consisted

in applying a potential difference to porcelain bodies which were varied in temperature and determined the dielectric strength of the porcelain at different temperatures. They made a large number of such bodies, of different composition and of a form adapted for use in an electrically heated furnace. They measured the potentials required to break down such insulators.

In general when such a body breaks down under electric stress a mechanical puncture results and the body ceases to become an effective insulator when again subject to high potentials. Messrs. Henderson and Weimar found that when a temperature of 300° C. was reached, they had difficulty in building up a potential to a value where a definite and sharp break indicated a puncture of the dielectric. Instead of obtaining such a definite value a rather indefinite one was obtained in which a phenomenon somewhat similar to break down occurred. They discovered also that when these insulators were cooled to room temperatures that their insulating properties had not been impaired in the slightest. This indicated that instead of producing a mechanical break down of the material such as was attained at lower temperatures, the failure to insulate was due to a change in conductivity of the bodies.

Soon after this, experiments were reported by A. A. Sommerville of Cornell University and W. W. Stifler of the University of Illinois* on the resistance of similar bodies at high temperatures. The methods employed were the usual Wheatstone bridge methods for determining resistance in which a small e. m. f. was used.

Fleming, in his discussion of cable insulation, points out that such a method is open to serious objection on account of the polarization of the dielectric.

The effect of applying an e. m. f. develops a back e. m. f. and the condition for establishing a bridge balance becomes a function of the true resistance of the arm containing the specimen and the e. m. f. of polarization as well. The whole question of the resistance of such bodies is an open one. The transmission of current through such bodies has been regarded at

* Physical Review, April, 1911, p. 429.

times as similar to metallic conduction, at other times as electrolytic in character. It is possible that these ceramic bodies function in both manners.

The author undertook these experiments without expectation of answering this question, but to obtain some experimental data on the magnitude of the currents obtained by Henderson and Weimar in their experiments, also to find if possible whether one could give a true ohmic value to the resistance offered by the porcelain bodies at temperatures where they became very appreciable conductors. Henderson and Weimar had used periodic e. m. f's. from a 60 cycle source. The general plan here adopted was to employ the high potential storage battery in our laboratory for maintaining constant and fairly high potentials (up to 1,000 volts) and apply the potentials directly to the specimen at the same time measuring the current. Then from Ohm's Law we could infer the resistance

$$V_1 - V_2 = RI.$$

$V_1 - V_2$ = potential difference in volts.

I = current in amperes.

R = resistance in ohms.

Figure 1 shows the very simple arrangement of the circuits. The battery has one terminal earthed. The other terminal was connected to the specimen (S) through a high resistance (R). A Weston volt meter (V) with a multiplier (M) measured the potential difference between the upper face of the specimen and the earth. The regulating resistance (R) made it possible to maintain a constant potential if desired. The regulating resistance was a liquid contained in a tube 80 cm. long, 2 cm. in diameter.

The liquid is a solution 25% saturated of Cadmium Iodide in Amyl alcohol. The terminals are Cadmium. This gives a high resistance quite free from polarization and capable of carrying currents of 50 milliamperes.

The ammeter (A) introduced between the specimen and earth measured the current passing through the specimen only. This consisted of a resistance with a D'Arsonval galvanometer in shunt. Knowing the resistance of shunt and galvanometer one can calculate the fall in potential through the specimen for any values given by the voltmeter. Through the courtesy of the Ceramics Department, samples of porcelain were secured

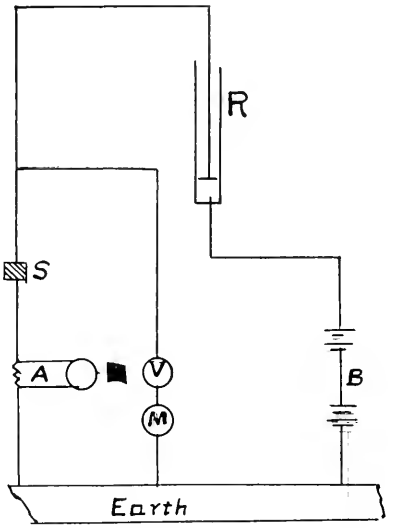


Fig. 1.

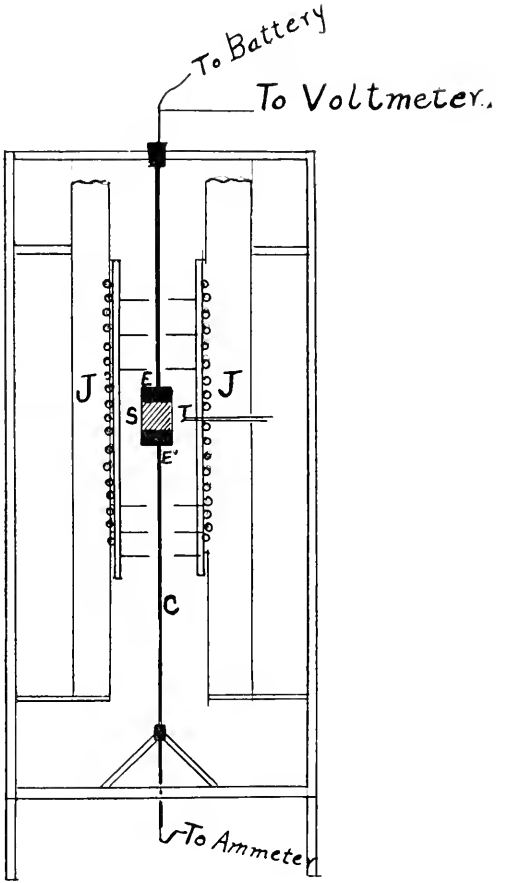


Fig. 2.

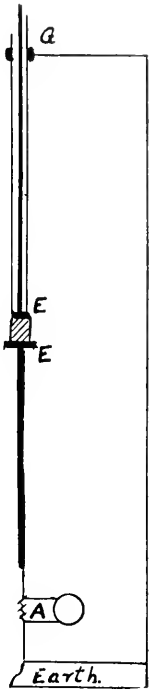


Fig. 3.

of the same kind as those used by Henderson and Weimar. These were moulded in the form of cylinders 2 cm. in diameter and 2 cm. in length. The ends were ground plane. The method of mounting and operating upon them is shown in Figure 2.

The furnace proper consisted of two porous battery jars with bottoms removed, placed end to end. Over this resistance wire was wound. This was covered with asbestos paste and baked on. The furnace was then placed in a section of asbestos steam pipe jacket. A thermo couple (T) projected into the chamber of the furnace. It was a Pt Rh-Pt couple which had been calibrated for other work.

A thick rod of copper (C) projected from below into the heating chamber. This rod had a copper cylinder (E) screwed to the top. The upper surface of the cylinder was covered with Platinum which was securely fastened to the copper cylinder both mechanically and electrically. This Pt surface served as an electrode which pressed against one face of the porcelain cylinder. Platinum was used because it would not oxidize at the temperatures attained. Above the specimen (S) a rod similarly terminated rested on the upper face of the cylinder. This rod had freedom of motion through guides. Changes in length due to expansion were provided for in this manner; it also insured that the specimen would be subjected to a constant pressure during the experiment. A series of mica vanes placed at intervals about the rod served to reduce heat losses due to convection.

Such a furnace can be regulated by hand, within reasonable limits. The large heat capacity and low conductivity of the materials entering into the construction serve to iron out small fluctuations of current strength. It was found that a steady temperature of 500° C. could be obtained five or six hours after turning on the current and that this could be maintained constant plus or minus 3° for a period of several hours. With such a device when a potential difference is applied, current flows through the ammeter. The specimen is so mounted that the stream lines of flow, such as we ordinarily consider, are perpendicular to the electrodes and parallel to the axis of the cylindrical specimen. The current we wish to measure is of this character. We will call this the Number One type. There

are two other possibilities. Number two, a possible creepage or leakage from one terminal to another over the surface of the porcelain.

Number three, a current passing through the hot gases surrounding the body.

The third type is present if we raise the temperature to a point where the interior begins to glow and apply a sufficiently high potential. When an appreciable current passes through the gas it becomes luminous and is readily observed. It is characterized by appearing suddenly when a critical potential is attained and is large compared with the Number One type of current. The effect can be avoided only by operating over potentials which should be kept below 350 volts. This places a decided limitation in the form of apparatus shown in Figure 2.

Anticipating the results slightly it may be said that leaving out of account the gas discharge, the current passing through the ammeter and through the porcelain appeared to be separable into two parts, one which decreases rapidly with time and one which if it changes at all changes at a much lower rate. It was thought that this might be due to some alteration in surface condition and this was borne in mind while making the tests in porcelain. It did not seem feasible to alter the form of apparatus to prevent the possible surface leakage in the case of porcelain. It may be remarked also that while the values of current strength differed somewhat from different cylinders, all results were of the same general character.

The next step in the experiment was to make a glass cylinder of the same form as the porcelain cylinders previously described. Only one such cylinder was used and while it showed appreciable conduction at lower temperatures than did the porcelain, the general characteristics of current-time were the same, namely, a large initial current which decreased with time.

Next a glass cylinder of the form shown in Figure 3 was used. This was designed to eliminate both the possibility of gas conduction and leakage over the surface. The glass cylinder was continued at the upper edge by a glass tube which extended nearly the entire length of the copper rod. A guard ring shown in the figure (R) was wound around this tube and earthed. The rod inside the tube rested on the glass cylinder as before and was terminated with platinum. In this case if

creepage over the surface occurred the leakage current would be diverted to earth and the ammeter would register only the current passing through the cylinder specimen, i. e., the Number One type. It was not convenient to make this cylinder of the same dimensions as the one previously used, but the characteristics of the current time curve were the same as in the previous cases. This would indicate that the characteristic curves of all were of the same kind and were due to the volume conduction of the specimens rather than leakage over the surface.

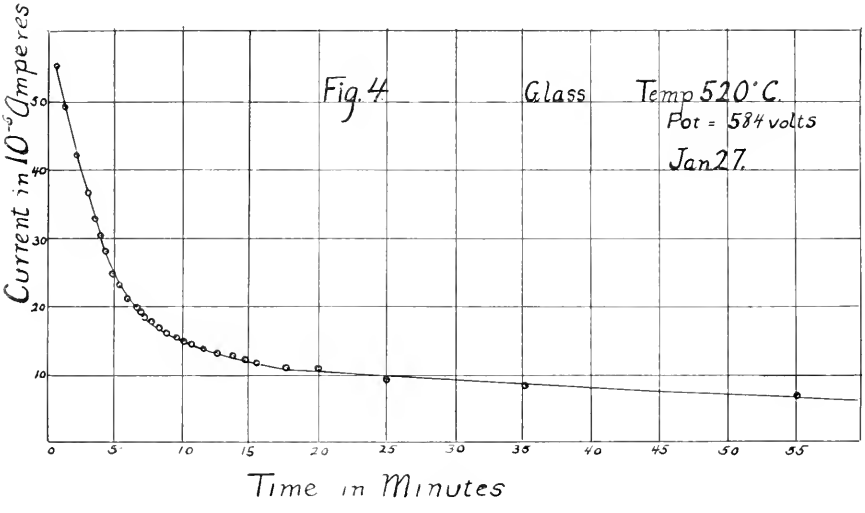
Discussion of Results.

A few preliminary trials indicated that it was not possible to fix the resistance of the porcelain or glass bodies by the simple application of the formula suggested earlier in this paper. The current strength was found to be a function of the material, dimensions, temperature and potential applied, also it depended upon the length of time of application of the e. m. f. The apparent resistance could have wide variations in value which seemed to be limited only by the time of application of the e. m. f. We are accustomed to think of the resistance of a conductor as having a definite and fixed value determined by the dimensions and temperature of the conductor. Our legal definition of the ohm is of this kind. In such a sense these ceramic bodies at temperatures where they become appreciably conducting have no definite resistance.

The usual method of study was to obtain a predetermined temperature and maintain it at a constant value through a single experiment. A potential was applied which was left constant and the current noted at time intervals. Figure 4 shows a typical curve. This was made on glass, with the guard ring arrangement, hence current values are for those which must pass through the glass.

The current decreases initially very rapidly with time and then at a much diminished rate. The units shown as ordinates are 10^{-5} amperes and on this scale the values may be shown over a long period. The first value shown in Figure 4 is one taken one minute after the potential was first applied. The earlier values are much larger and cannot be shown on this scale. The general procedure was to take current readings every 15 seconds during the early stage for say five minutes,

then at minute intervals and finally at much greater intervals. When a new specimen is taken the initial currents are of the order of several milliamperes for a few seconds. Such measurements were made but it is difficult to obtain accurate current measurements where the values diminish so rapidly. The difficulty which Henderson and Weimar experienced in obtaining definite break down readings are, I think, a little better understood from the nature of these curves. In using a 60 cycle current a potential which increased from zero value to maximum value in 1-240 of a second was applied; this decreased



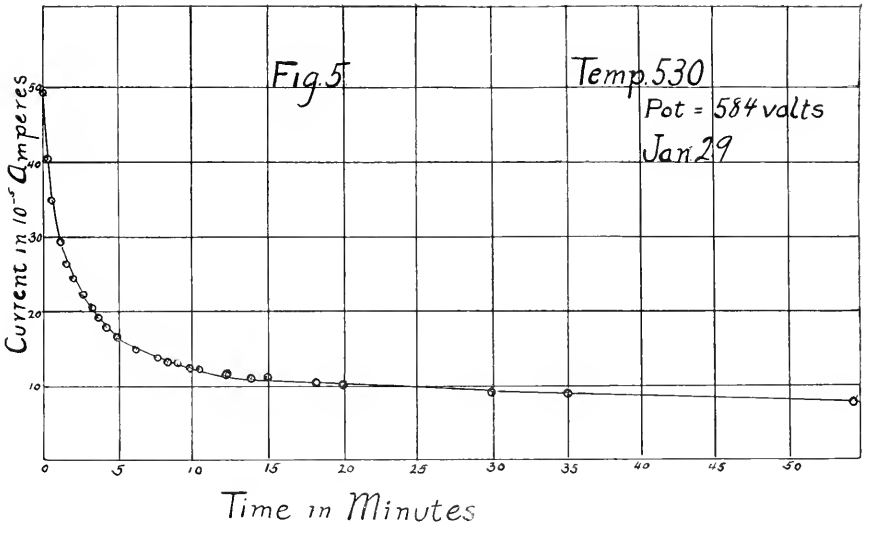
to zero and was then reversed in direction. In such intervals of time only a feeble back e. m. f. is developed and the current no doubt has a large value. Their difficulty in building up a definite potential was due to the fall in potential which occurs when a current passes. The continued decrease in current as time progresses is due undoubtedly to a back e. m. f. which may attain any value short of the applied e. m. f.

Persistence of the back e. m. f.—A considerable part of the experimental work in this connection was done in studying the ability of these bodies to retain an e. m. f. set up in them.

It was found for example that after the curve had been followed out to the flat portion, that the e. m. f. might be removed for a short time (say two minutes) and the curve

taken up on reapplication of the e. m. f. without any discrepancy. If a half hour elapsed the first values would be somewhat larger than when the e. m. f. was withdrawn.

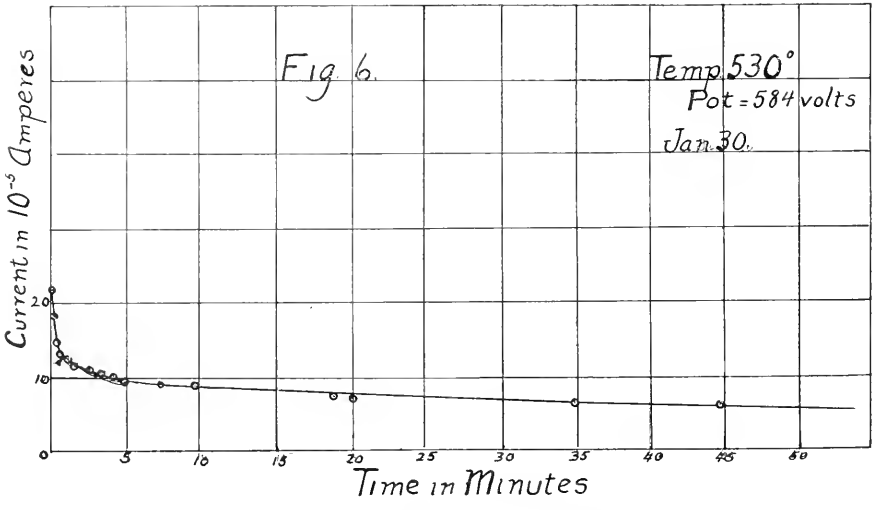
In some cases after application for a half hour in one direction the battery was reversed. The effect of this was to have the impressed e. m. f. of the batteries acting in the same direction as the previously generated back e. m. f. The time current curve showed this boosting effect, the initial values of the current were larger and the time taken for the curve to attain the flat portion was much longer.



This boosting effect was apparent even when the specimen was cooled to room temperature and reheated. The reversal was effected in two ways: First, by reversing the battery; Second, by taking the specimen out after cooling and turning it end for end. This latter process had the effect of reversing the specimen only leaving the terminals unaltered. The effect was the same and the effect of previous polarization was unmistakable.

Figures 5 and 6 are companion curves for Figure 4 and are introduced for the purpose of showing the retention of the polarized state. Figure 4 is the first run made in a glass cylinder which, so far as I had means of knowing, had never been treated electrically.

The first reading shown was taken one minute after the potential was applied. This was permitted to cool to room temperature and remain in that condition without the application of a potential for two days. The specimen was reheated to approximately the same temperature as before and the same potential applied. Figure 5 shows the result on the same scale. The first reading shown is smaller than the first one in Figure 4 and was taken 15 seconds after the potential was applied. The potential indicated was left on for four hours and the specimen then allowed to cool. It was reheated after 20 hours and the curve in Figure 6 obtained.



This and many similar experiments show that the resistance of bodies of this character cannot be determined in a satisfactory way by direct current measurements. The behavior of the body is determined in part by its previous history. In this respect it is analogous to the behavior of magnetic bodies. It would be of interest to put these bodies through a cycle such as is done in the study of magnetic hysteresis. In fact a possible way of throwing more light on the interesting and difficult subject of dielectric hysteresis might be carried out in this manner. The author had in mind attempting such a series of experiments, but the close temperature regulation required and the length of consecutive time required to take a series of observations did not appear feasible for one carrying a teaching schedule.

Physical Laboratory, Ohio State University, December, 1915.

EVAPORATION AND PLANT ZONES IN THE CEDAR POINT MARSH.*

PAUL B. SEARS.

Yapp[1] in trying to account for the xerophytic structure of marsh plants by means of evaporation studies has shown a definite correlation to exist between the strata of marsh vegetation and rates of evaporation at corresponding levels. The following studies were made in an attempt to discover what additional correlations, if any, exist between distribution of marsh plants and the evaporational power of the air at different portions of the habitat. While the exact quantitative significance of such work as the following may be brought into question, as it often is, the striking results obtained by Transeau,[2] Livingston,[3] Fuller,[4] Weaver,[5] Yapp,[1] and others, show that when such work is carefully done it is of unusual efficiency, considering its extra-laboratory character.

The studies were carried on in the strip of marsh between Beimiller's Cove and Fred's Cove, at Cedar Point, Ohio. The physiography of this region has been beautifully worked out by Mosely,[6] while we are indebted to Jennings[7] for an excellent account of the phytoecology of Cedar Point. A glance at the accompanying maps[8] will make clear the nature of the region studied. It is a cove marsh along the inside of the lengthy sand-bar (Cedar Point) which, forming across the sunken mouth of the Sandusky River, has served to practically separate Sandusky Bay from the rest of Lake Erie. Save for the occasional violent northeasterly winter gales which have served to pile up Cedar Point, the prevailing winds here are largely from the southern and western quarters of the compass.[9]

Zonation is certainly the most obvious phenomenon of plant distribution in the marsh, and was chosen as the feature most profitable for investigation. Beginning with the outermost zone of severely exposed vegetation the following clearly defined zones are encountered in order:

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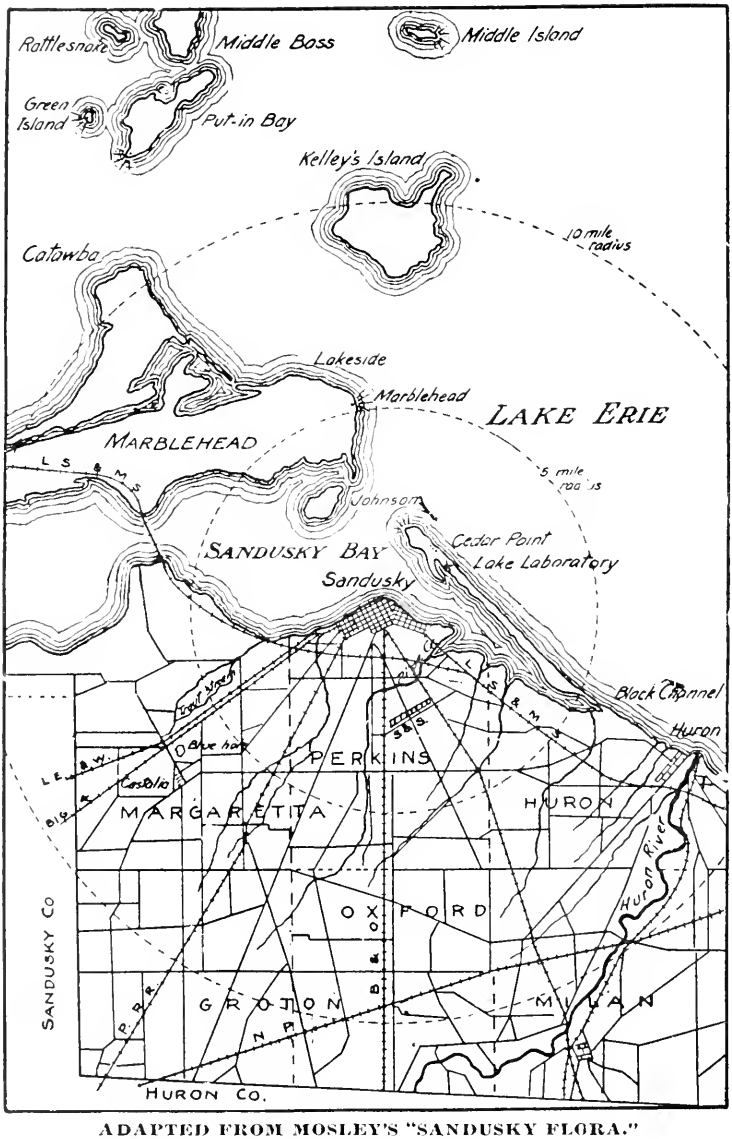
* Contribution from the Botanical Laboratory of the Ohio State University, No. 93.

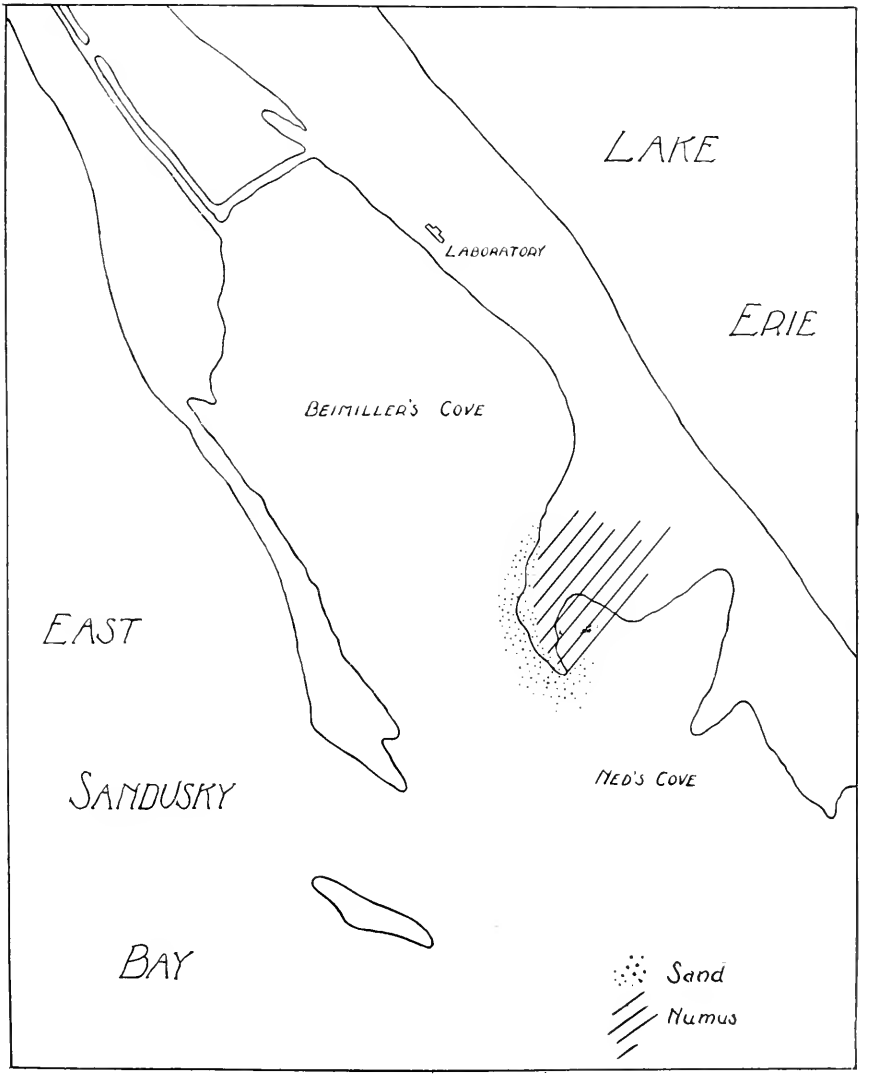
The Scirpus Zone—This is a region of extreme exposure so far as vegetation is concerned, and includes points 50 to 100 feet (15 to 30 metres) offshore from the bar. The water here



ADAPTED FROM MOSLEY'S "SANDUSKY FLORA."

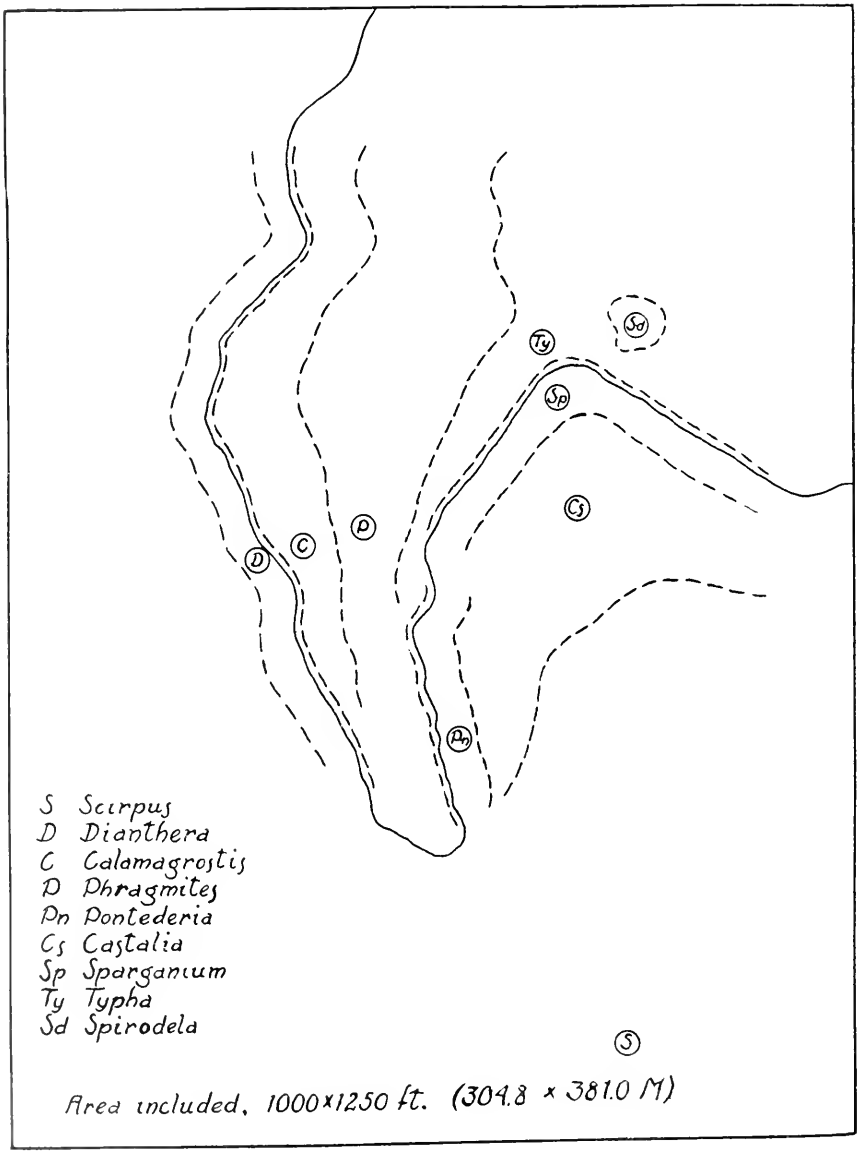
is about three feet (.9 metre) in depth, with a sandy, much-washed bottom. The only form of emersed plant life here is *Scirpus validus* in more or less scattered clumps.

The Dianthera Zone—This comprises the western and southwestern edge of the bar, as indicated on the map, Fig. 3, and is consequently more or less exposed to the prevalent winds. The



water depth here ranges around six inches (1.5 decimetres), with a bottom that is sandy, well washed, and that has a very slight admixture of dark organic material indeed. The domi-

nant species here is *Dianthera americana*, present in considerable abundance, with a few plants of *Scirpus americanus*, *Scirpus nanus* and *Carex* sp.



The Calamagrostis Zone—Wherever the sandbar actually rises above water level, it is covered with this distinctive type of vegetation. Anything above the height of the *Dianthera*

here receives considerable exposure to the winds from the prevailing quarter, obviously. The soil is almost pure sand, averaging about four to six inches (1 to 1.5 decimetres) above water level. The vegetation in this area so restricted is almost exclusively *Calamagrostis canadensis* with scattered and small individuals of *Salix longifolia*.

The Phragmites Zone—Behind the Zone just mentioned the sandbar extends for some distance, but is nowhere emersed. The depth of water at this portion of the habitat fluctuates, generally being less than three inches (.7 decimetres), and the sand contains a considerable amount of organic material. *Phragmites phragmites* flourishes here almost exclusively, the only invaders being occasional sickly plants of *Dianthera* and scattered small colonies of *Spirodela polyrhiza*. The luxuriant tops of the *Phragmites* compel rather wide basal spacing of the plants, giving room for such invasion as does occur.

The Pontederia Zone—Along the inner or northeasterly edge of the sandbar just mentioned the water again deepens, composing an extremely sheltered zone, hence one very rich in organic detritus. The water depth here ranges between six and twelve inches (1.5 and 3 decimetres), and the dominant species is *Pontederia cordata* while *Sagittaria latifolia* is present in considerable amount, with *Carex* sp. and stragglers of *Dianthera* and *Sparganium*.

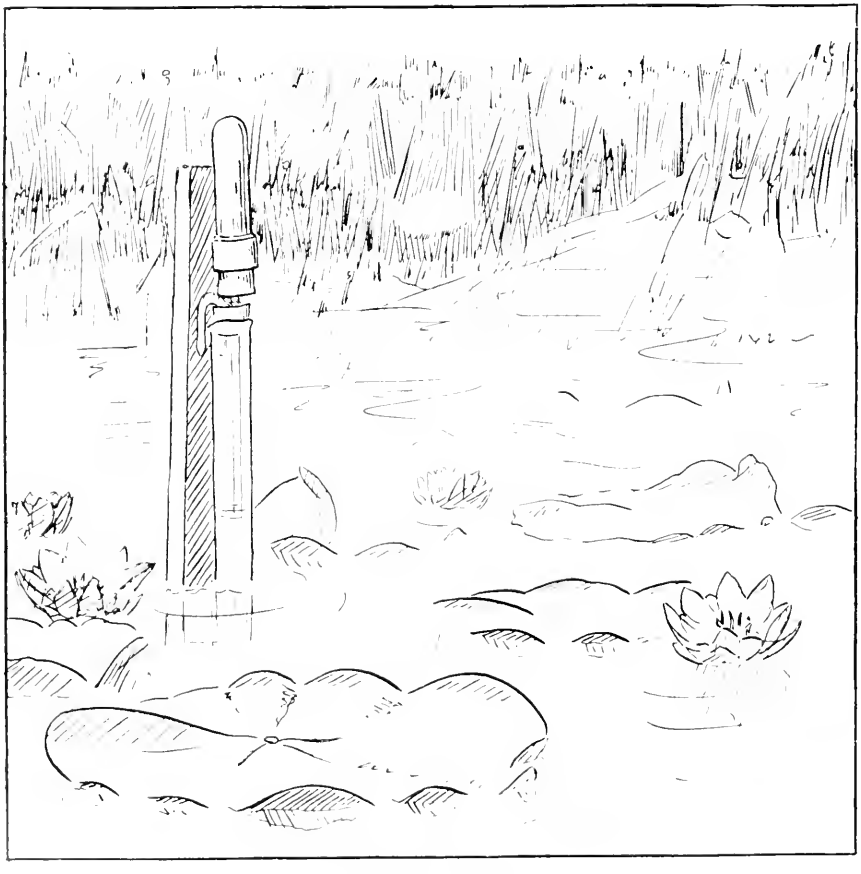
The Castalia Zone—The sandbar mentioned above is sufficiently long to form a tiny sheltered cove to the northeast, as a glance at the map will show. Actually this little cove is a mere recess at the western end of the larger Ned's Cove. Needless to say the bottom here is heavily covered with mucky organic matter, and the water, which ranges from one to four feet (.3 to 1.2 metres) is quiet. The conspicuous and abundant species here is *Castalia tuberosa*, while there is a plentiful admixture of *Nymphaea advena*, *Nelumbo lutea*, *Utricularia vulgaris*, *Potamogeton natans et sp.*

The Sparganium Zone—Fringing the northerly border of the cove, but in other respects like the *Pontederia* zone which fringes its western border, we find the next distinctly marked type of vegetation, which is an almost pure stand of *Sparganium eurycarpum*.

The Typha Zone—Inside of the fringe of *Sparganium* just mentioned, and extending in all directions until it encounters regions seized by *Phragmites*, lies the clear-cut cattail habitat.

Like the last several zones mentioned, it has a bottom rich in humus, while the water ranges from six to twelve inches (1.5 to 3 decimetres) in depth. *Typha latifolia* grows here to the practical exclusion of everything else, save for an occasional space which may be called—

The Spirodela Habitat—These spaces are usually a couple of yards or more (1 to 2 metres) in diameter, and are open areas of water rather closely hedged in by *Typha*, with occasional straggling plants of *Sparganium*. The water here is, of course, quiet and usually about three to six inches (.7 to 1.5 decimetres) in depth, richly strewn with colonies of *Spirodela polyrhiza* and *Lemna trisulca*, principally the former.



The Castalia Station

On June 29th an instrument was set up in each of the zones indicated and daily morning readings taken, with the exceptions and interruptions shown in the table, until July 22nd, when the last readings were made. The corrected totals given in the table are for the actual number of days during which every instrument was in working condition. It may be fairly asserted that this period covers, in spite of its shortness, a critical time of year for vegetation so far as actual transpiration is concerned. It will also be noted in the table that all figures have been reduced to a percentage basis, using the lowest total as 100%.

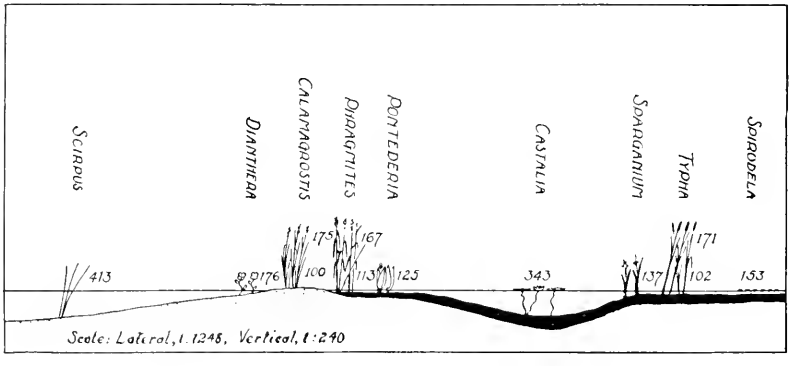
TABLE SHOWING DAILY WATER LOSS FROM EACH INSTRUMENT DURING TIME OF EXPERIMENT.

Abbreviations for Stations as on Map, Fig. 3.

	S	D	C UPPER	C	P UPPER	P	Pn	Cs	Sp	Ty UPPER	Ty	Sd
June												
29	.....	25	26	10	19	3	.....	29	9	.....	7	18
30	.....	14	15	11	11	6	.....	21	12	.....	6	15
July												
1	.....	21	24	13	19	13	.....	44	19	.....	18	18
2	.....	10	6	4	5	3	.....	12	8	.....	5	7
3	35	17	17	9	13	11	14	26	12	14	9	13
4	19	10	9	4	12	5	12	17	8	10	7	9
5	35	17	17	11	9	8	7	28	11	13	8	12
6	36	18	18	7	18	14	18	28	15	14	9	14
7	28	11	12	6	4	8	11	27	10	11	8	10
8	53	10	22	10	18	14	11	42	21	25	16	19
9	34	16	18	7	14	10	14	29	15	15	9	14
10	39	14	18	7	18	10	15	30	13	15	10	13
11	.....	27	23	12	12	13	15	44	16	20	15	20
12	.....	15	13	6	14	7	9	30	12	11	7	13
13	.....	16	20	10	17	13	16	35	16	22	5	13
14	.....	13	12	7	11	10	7	18	10	17	7	9
15	.....	3	4	.....	2	1	1	3	2	1	0	2
16	.....	12	15	5	15	10	8	24	9	15	8	10
17	38	17	16	9	15	8	7	40	11	16	11	13
18	67	27	23	19	27	16	15	53	18	25	9	26
19	62	28	19	13	32	16	16	47	21	27	14	23
20	49	19	19	13	16	15	10	41	13	18	11	18
21	51	23	26	16	25	15	16	45	14	23	14	18
22	48	14	25	12	26	16	16	.....	14	20	10	17
Net Total	546	233	234	132	221	150	166	453	182	226	135	202
Per c'tage	413	176	175	100	167	113	125	343	137	171	102	153

Standardized porous cups mounted as shown over ordinary 100 cc. graduates, with curved tubes for equalizing the air pressure, were used. When set at ground or water-level, this gave a means of measuring the drying power of the air at 11–14 inches (2.7–3.5 decimetres) up.

At each station (see map, Fig. 3) an instrument was set at this lowest possible level. At the *Scirpus* station an anchored raft was utilized, to which the evaporimeter was stoutly lashed, while at the other stations the instruments were fastened to firmly set cypress stakes. In the *Calamagrostis*, *Phragmites*, and *Typha* zones the stakes were of sufficient height to allow the location of a second instrument approximately four feet (1.5 metres) above the first.



Composite Profile Showing Evaporation Percentages.

All readings were taken by myself to eliminate error due to personal equation, and were taken from the bottom of the meniscus. So often as necessary the graduates were carefully refilled to the 100 cc. mark.

That the profile, Fig. 5, is a composite is readily seen from the zone map, but it has been chosen as affording the most graphic means at hand of setting forth at the same time the majority of relative habitat conditions and the evaporation percentages obtained. The profile will be better understood if it is borne in mind that the left-hand side represents the quarter from which the prevailing winds come, and that during the days for which the corrected totals were figured the actual wind movement from that quarter was 202 miles in excess of that from the opposing quarter,[9] which moreover is strongly sheltered by Cedar Point itself.

The *Scirpus* zone, with its maximum exposure to wind and light, shows the highest rate by far—413%. It seems not improbable that to survive in such an environment the *Scirpus* must possess unique characters beyond its undoubted ability to withstand the heavy beating of surf, which Jennings[7] mentions.

The zone characterized by *Castalia* and *Potamogeton* ranks second, with an evaporation percentage of 343. While not directly exposed to severe winds this zone is undoubtedly one of rather free air movement, and certainly one of continual and merciless exposure to the sun. The relatively high rate of evaporation here may well be the factor that is prohibitive of emersed forms, other than stray plants of *Scirpus*, although the factor of water depth cannot be ignored.

That this habitat is a rigorous one for plant life is further shown by the fatal effects of a day's exposure of the under side of a *Castalia* leaf to the air of its habitat, whether by a continued light breeze from the proper quarter, or by accident or experiment. This phenomenon, which it is interesting to compare with "wind-burning" as noted by Gates,[10] was frequently observed during the course of the work here described.

Dianthera is a plant characteristic of washed sand bottoms,[7] a condition implying more or less exposure, and in this marsh it is found under conditions of evaporation distinctly comparable with those obtaining in the windswept tops of *Calamagrostis*, at an elevation of five feet (1.5 metres).

The remaining figures are chiefly valuable as showing rather strikingly the modifying power of vegetation on evaporation. Especially marked is the difference between the nearby instruments in the *Spirodela* and *Typha* zones, respectively, at the same level. Likewise the waterloss is much greater at the same level in the case of low-growing than of high-growing vegetation. Moreover the instrument standing in the compact and sheltered lower layers of the *Calamagrostis* lost decidedly less than the one in the leafless and wide spaced lower layers of *Phragmites*.

Finally the differences between upper and lower stations in *Calamagrostis*, *Phragmites* and *Typha* respectively, are ample enough to confirm Yapp's observation[1] that different strata of marsh vegetation afford vastly different habitat conditions, as regards the evaporational factors. This is not the less true because none of the three zones mentioned happen to show any distinct stratification.

Summary and Conclusions—Transpiration loss, so far as measured by the evaporating power of the air, is definitely correlated with physical exposure and zonal distribution of plants in the marsh studied.

Topography, substratum, direction of prevailing wind, and thickness of vegetative cover all find logical expression in the evaporation percentages obtained.

Evaporation must be assigned an important role coordinate with such fundamental factors as water depth and organic content of substratum in interpreting the plant distribution in the marsh under examination.

The writer feels under considerable obligation to Dr. Raymond J. Pool, of the University of Nebraska, Dr. E. N. Transeau of Ohio State University, and to the staff of the Ohio State Lake Laboratory for courtesies and suggestions during the course of the work and the writing of the paper presented above.

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A METHOD FOR THE RENEWAL OF PLANT NUTRIENTS IN SAND CULTURES.

A. G. McCall.

The recent publications of Tottingham* and of Shive† have suggested the desirability and importance of having some method by which the effect of different nutrient solutions upon plant growth might be studied in the presence of some solid substance similar to the soil, but at the same time furnishing fewer chemical and biological complications. Acting upon this suggestion the writer has devised a method by which seedling may be grown in sand and the nutrient solution renewed or modified almost as readily as in water cultures. In duplicating in sand some of Shive's work with wheat seedlings in solution cultures, use was made of graniteware pots approximately 12 x 12 centimeters inside, tapering slightly at the base and having a wide projecting rim at the top and a capacity of 1500 grams of dry quartz sand when filled to within about three centimeters of the top. To provide for the removal of the solution a small lead tube was soldered into the side as near the bottom as possible. The soldered joint and the lead tube was covered with paraffin to guard against lead poisoning and the outlet closed by means of a short length of rubber tubing provided with a pinch cock. The description of the method given in the following paragraphs includes the details of manipulations from the starting of the seedlings to the harvesting of the plants. The seed is soaked in water and the seedlings grown in the manner described by Tottingham‡, to a height of about three or four centimeters, when they are ready to be transferred to the sand cultures. While the seed is being germinated 1500 grams of dry quartz sand (previously washed several times with distilled water) is weighed into the pot, the outlet at the bottom of the pot being screened on the inside by means of a plug of glass wool inserted before the pot is filled. With the pinch cock closed distilled water is now added to the pot until the sand is completely saturated, after which the pinch cock is opened and the surplus water is allowed to drain out through the tube at

*A Quantative Chemical and Physiological Study of Nutrient Solutions for Plant Cultures. Physiological Researches Vol. I, No. 4, May, 1914.

†A Three-Salt Nutrient Solution for Plants. Amer. Journal of Botany, 4:157-160, April 1915.

‡Tottingham. p. 176.

the bottom of the pot until the last free water has disappeared from the surface of the sand. A hemispherical clay funnel is placed in position as shown in the photograph and the pot is ready to receive the seedlings. After careful selection for uniformity, the seedlings, six in number, are planted equal distances apart on a circle drawn midway between the edge of the funnel and the wall of the pot. Care is taken to have the

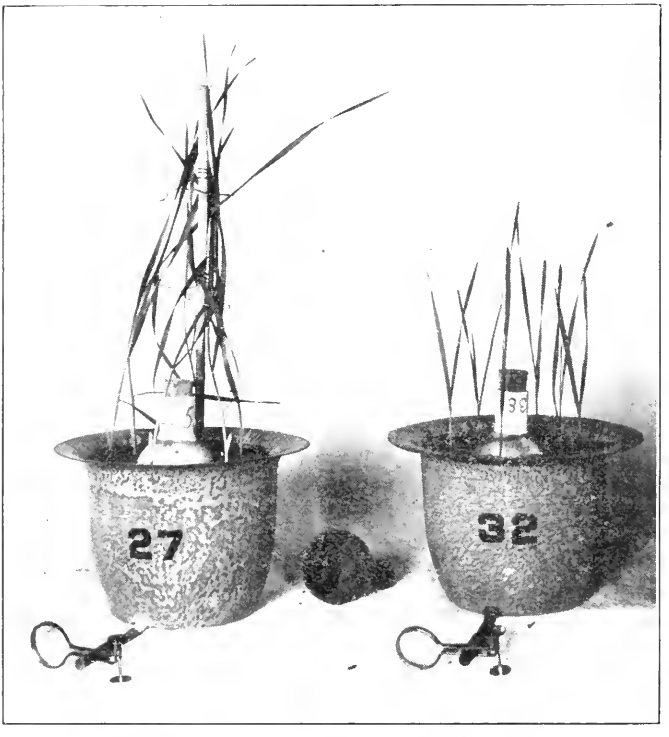

Fig. 1. Granite-ware pots for the study of plant nutrients in sand cultures.

seedlings at such depth that the top of the grain is just level with the surface of the sand. After all of the seedlings are in place the pinch cock is closed and the pot is tapped gently on the top of the table until free water appears on the surface of the sand. This manipulation serves to pack the sand around the roots of the seedlings and at the same time to level off the surface of the sand preparatory to putting on the seal of Briggs and Shantz* wax.

*Bul. No. 230, Bureau of Plant Industry, U. S. D. A., p. 13.

The surplus water is then drawn out of the pot by application of suction (by means of an aspirator) to the tube at the bottom and a thin layer of the melted wax is flowed over the surface, completely covering the surface of the sand between the funnel and the wall of the pot. Care should be taken not to have the wax too hot otherwise the seedlings may be injured at the point of contact between the wax and the plant. The surface must be sealed to prevent loss of water by evaporation from the surface of the sand and of course the walls of the pot must be impervious to moisture in order that transpiration can be measured and the concentration of the nutrient solution controlled. The pot is now ready to receive the nutrient solution, which is added through the funnel at the top while the water is being removed at the bottom by the application of suction to the outlet tube. A double or triple portion of the nutrient solution is passed through the sand at this first application in order to flush out the distilled water. The pot is now placed on the scales and the removal of solution is continued until the sand has been reduced to the desired moisture content which should be as near the optimum as possible. At the end of each three-day period the pot is weighed and sufficient water is added through the funnel to bring the system back to its original weight. A fresh nutrient solution is now added in the desired amount (250 cc. for pots of this size), while an equivalent amount of solution is removed at the bottom. A nutrient solution of the same concentration may be used throughout the entire growth period or it may be varied from time to time as the plants continue to develop.

The plants may be harvested at any time by removing the wax seal and cutting off the plants level with the surface of sand and, if desired, the roots may be recovered from the sand by washing them out with a jet of water. The weight records will give the transpiration of each culture and the harvest records can be made to include the dry weights of both tops and roots. This method also furnished a means by which the original concentration of the solution can be compared with its concentration after contact with the soil and with the plant roots. The method is superior in many ways to water cultures because it permits the plants to be grown under conditions that approximate those found in the field, so far as the sub stratum is concerned, and it seems probable that with some slight modifications which are now in progress it will be possible to apply the method to cultures grown in sandy and sandy loam soils.

Department of Agronomy, Ohio State University.

ADDITIONS TO THE CATALOG OF OHIO VASCULAR PLANTS FOR 1915.

JOHN H. SCHAFFNER.

The following species have been added to the list of Ohio Plants. The numbers refer to the list as originally published or are additions of new species inserted at the proper places.

53.1 Equisetum kansanum Schaffner. Kansas Horsetail. Massillon, Stark County. Collected 1906. L. S. Hopkins.

68. Pinus strobus L. White Pine. Raven Rocks, Belmont County. An isolated group near the Monroe County line. Emma E. Laughlin.

158. Stenophyllus capillaris (L.) Britt. Hair-like Stenophyllus. Kent, Portage County. L. S. Hopkins.

216.1 Carex suberecta (Olney) Britt. Prairie Straw Sedge. Brush Lake, Champaign County. John H. Schaffner and Fred J. Taylor.

324. Poa debilis Torr. Weak Spear-grass. Phalanx, Trumbull County. Almon N. Rood.

419. Panicum agrostoides Spreng. Agrostis-like Panic-grass. Kent, Portage County. L. S. Hopkins.

427. Panicum philadelphicum Bernh. Philadelphia Panic-grass. Phalanx, Trumbull County. Almon N. Rood.

595. Liparis liliifolia (L.) Rich. Large Tway-blade. Ironton, Lawrence County. Lillian E. Humphrey.

601. Corallorrhiza wisteriana Conrad. Wister's Coral-root. Berrysville, Highland County. Katie M. Roads.

770.1 Oxalis acetosella L. White Wood-sorrel. Raven Rocks, Belmont County. Emma E. Laughlin.

875.1 Viola cucullata Ait. Marsh Blue Violet. Parma Township, Cuyahoga County. E. L. Fullmer.

1118. Trifolium reflexum L. Buffalo Clover. Alledonia, Belmont County. Emma E. Laughlin.

1559. Agalinis skinneriana (Wood) Britt. Skinner's Gerardia. White-flowered form. Southeastern part of Fulton County. J. S. Hine.

1786. Triosteum angustifolium L. Yellow Horse-gentian. Ironton, Lawrence County. Lillian E. Humphrey.

PLANT DISEASE EXHIBIT CASES.*

LEO E. MELCHERS.

Recently the writer had occasion to prepare various sets of plant disease exhibit frames or cases for county and state fair exhibition purposes. Numerous types of trays, boxes and frames of various shapes and sizes have been given a trial by the writer, but the type to be described in this article, appears to be the most practical and serviceable for exhibiting specimens other than those which must be preserved in jars. In order to meet the requirements which are essentially necessary for an attractive, but still serviceable plant disease exhibit case, the following things must be taken into consideration:

1. The exhibit must withstand rough handling in shipping or otherwise.

2. The size of the shipping boxes or trunks in which the cases are packed, must comply with the compulsory regulations of railroad companies, if one wishes to take them along as baggage. Boxes or trunks beyond a certain length will not be accepted by railroad companies.

3. One person should be able to handle these frames without difficulty.

4. They should be constructed of light material, but still they must be durable.

5. Glass should be avoided on account of its fragility and weight. Celluloid is more satisfactory.

6. The frames should be constructed so as to withstand stacking in a box or trunk when shipping from place to place.

7. The case should be of a size which will accomodate two types of specimens: (1) entire cereal plants; and (2) fragments of plants, such as leaves affected with spots, cankers on limbs or twigs, etc.

8. They should be deep enough to accomodate such pathological specimens as cankers on limbs; but, on the other hand, so designed that they will satisfactorily accomodate cereals, leaves, etc.

9. They must appear neat and attractive.

10. The cost of construction should be reasonable.

*Kansas State Agricultural College, Manhattan, Kansas.

In order to meet the above requirements, the writer attempted to construct a case which is not expensive, yet attractive and well designed to display plant diseases to the best advantage.

A working plan of this case is shown on Fig. 3. The outside measurements of the case are 24″ x 40,″ the inside measurements being 22½″ x 38½″. The sizes of the two kinds of partitions

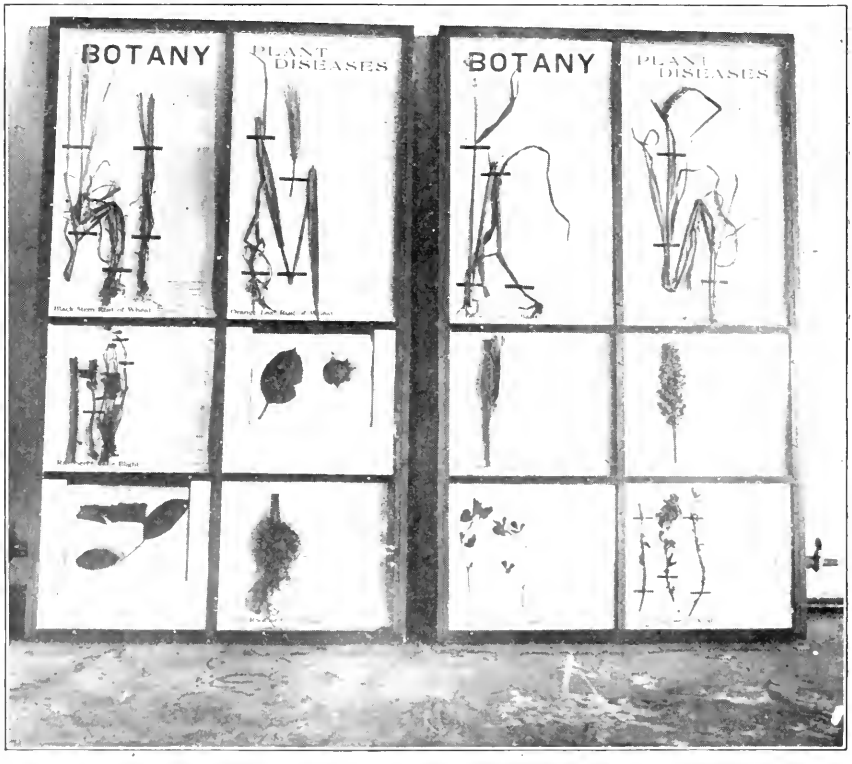

Fig. 1. Exhibit case showing specimens of two sizes. (Photo by L. E. Melchers.)

are 9¼″ x 11″ for the smaller, and 11″ x 19″ for the larger. The arrangement of the partitions may be changed to meet the requirements. Besides the arrangement as illustrated, either eight compartments 9½″ x 11″, or four 19″ x 11″, may be made. The 19″ x 11″ size is best adapted for such specimens as cereals, weeds, etc., while the smaller are sufficiently adequate for the majority of pathological specimens, such as cankers, leaf-spot diseases, etc. See Fig. 1.

Fig. 2 illustrates a frame of similar construction, but designed for displaying photographs. The trays is only one-half inch deep. A quarter-inch, quarter-round molding is used to hold the celluloid and cardboard mounting in place. The crosspieces are likewise quarter-inch, quarter-round strips. The celluloid protects the photographs, and may be wiped off with a damp cloth without injury to itself or photographs.

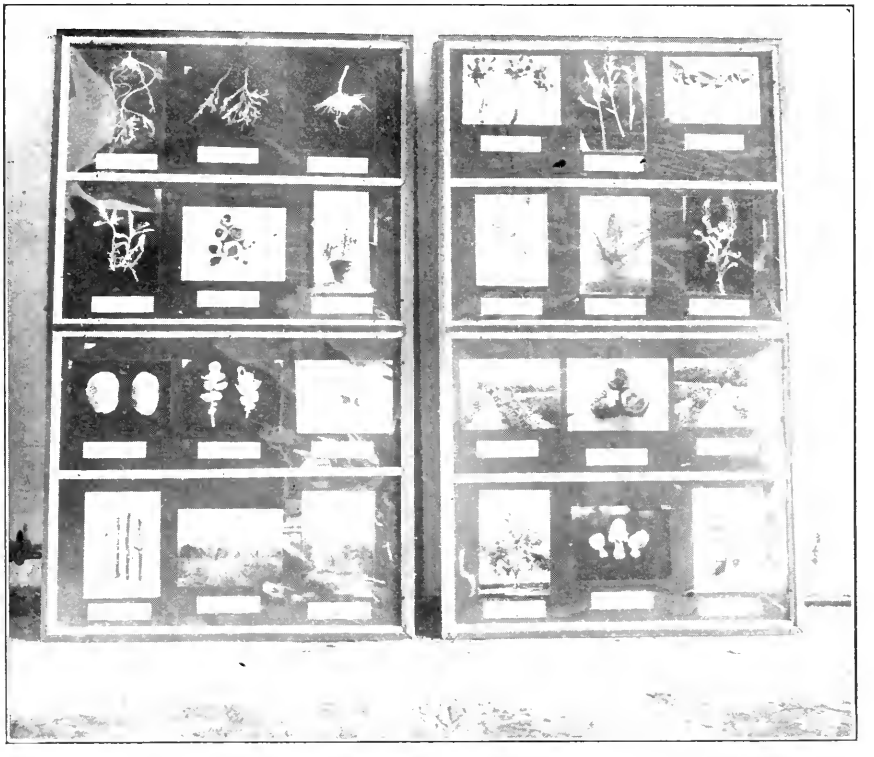

FIG. 2. Exhibit case showing arrangement for photographs. (Photo by L. E. Melchers.)

PREPARATION OF MATERIAL FOR EXHIBIT CASE.

Various types of plant disease material may be placed in a case of this design. Most of the specimens shown in the accompanying illustration were dried and pressed. These were glued on, and fastened by means of tape to three-ply white cardboard, of the proper dimensions, in the ordinary manner. Where bulky specimens, such as raspberry canes, Kafir heads, etc., were used, fine wire was employed.

The writer finds that Riker specimen mounts, $6\frac{1}{4}''$ x $8\frac{1}{4}''$ or larger, are well adapted for some purposes in connection with these cases.

Cankers of fruit trees, plaster-cast specimens, fragile specimens, or specimens contained in glass tubes, are completely protected and kept intact, if first put into one of these mounts, and then placed into one of the compartments. If Riker mounts are used, they must be fastened into place inside the

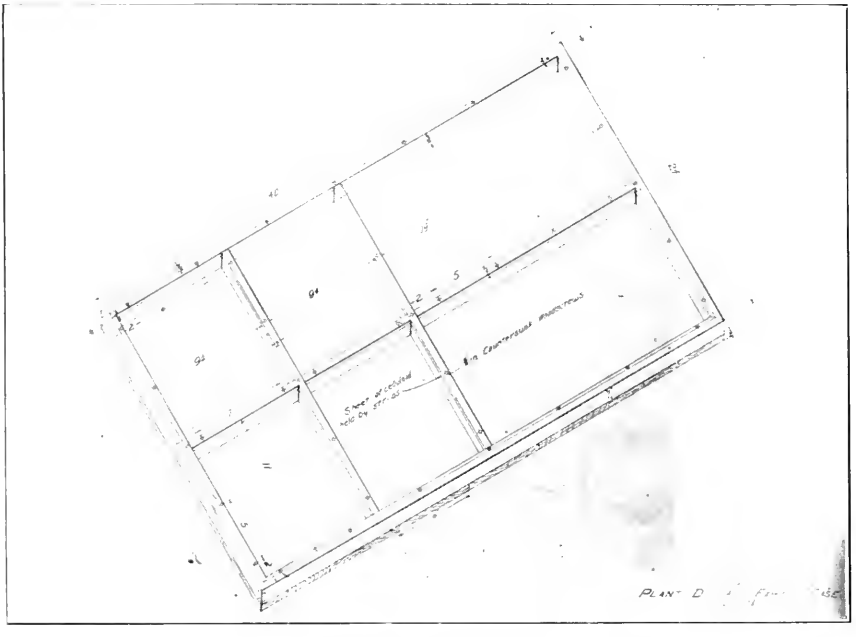

FIG. 3. A working plan for a plant disease exhibit case.

compartment, by nailing blocks of wood, as braces, up against the sides of the Riker mount. The nails are driven through these blocks and into the bottom of the frame. The wooden blocks act merely as braces to prevent the mount from shifting in the compartment.

The different specimens will naturally vary in thickness. The mounted specimens should be in close contact with the celluloid. In order to attain this, cotton is used to fill up the difference in depth between the thickness of the specimen and the depth of the compartment. Where Riker mounts are

employed, the blocks and intervening spaces are covered and filled with cotton. After the mounted specimens are placed into their respective compartments, the celluloid should be placed over one-half of the frame. The sheets of celluloid comes in sheets 20″ x 50″. One sheet will cover the entire frame, but necessarily in two pieces, allowance being made for overlapping at the center crosspieces and fastening to the edges of the frame. (See working plan). For the specimen cases, oak strips 3/16″ x 5/16″ are employed to fasten the celluloid in place, these being a part of the frame. The other strips for the cross-partitions are ½″ wide. These strips are fastened with small screws, (counter sunk), which pass through the celluloid and into the frame proper.

The weight of one of the specimen cases when completed and containing the specimens, is about 13 pounds. The total cost is approximately $2.50.

The Material Necessary for the Construction of One of the Specimen Cases:

Oak,	16′ x ½″ x ¼″
Cypress,	8′ x ½″ x 1″
	12′ x 1″ x ¾″
	12′ x ½″ x 6″
	2′ x ½″ x 4″
Celluloid,	20″ x 50″ (10/1000″ thick)
Screws,	32, gun-metal, flat-headed, ¾″

OHIO ACADEMY OF SCIENCE.

QUARTER-CENTENNIAL ANNIVERSARY.

The Twenty-fifth Annual Meeting of the Ohio Academy of Science was held at the Ohio State University, Columbus, on Friday and Saturday, November 26 and 27, 1915, under the presidency of Professor J. Warren Smith, of Columbus.

Owing to the anniversary character of the meeting, the usual program of volunteer papers was replaced by a series of invited addresses, as follows:

Presidential Address—Agricultural Meteorology, Professor J. Warren Smith, United States Weather Bureau, Columbus.

Address—Applied Meteorology and the Work of the Weather Bureau, Doctor Charles F. Marvin, Chief United States Weather Bureau, Washington, D. C.

Address—The Relation of the Academy to the State and to the People of the State, Dr. T. C. Mendenhall, Ravenna.

Historical Sketch of the Ohio Academy of Science, Professor William R. Lazenby, Ohio State University, Columbus.

Reviews of Scientific Progress in the Quarter Century.

Geology, Professor Frank Carney, Denison University, Granville.
Botany, Professor Bruce Fink, Miami University, Oxford.
Physics, Professor Frank P. Whitman, Western Reserve University, Cleveland.
Zoology, Professor Edward L. Rice, Ohio Wesleyan University, Delaware.
Chemistry, Professor William McPherson, Ohio State University, Columbus.
Archaeology, Professor G. Frederick Wright, Oberlin College, Oberlin.

At the supper, held Friday evening at the Ohio Union, short addresses were given by visiting delegates from other scientific societies. Governor Willis had expected to be present and to speak, but was unavoidably prevented at the last moment.

Notice was received of the appointment of the following delegates. Those marked with the asterisk were present at the meeting.

American Association for the Advancement of Science—*Professor L.O. Howard, Washington, D. C.

Boston Society of Natural History—*Professor Frederick C. Waite, Cleveland, Ohio.

Chicago Academy of Science—Doctor Frank C. Baker, Chicago, Ill.

Indiana Academy of Science—*Doctor D. W. Dennis, Richmond, Ind.; Mr. E. B. Williamson, Bluffton, Ind.

Iowa Academy of Science—*Professor Herbert Osborn, Columbus, Ohio; Doctor Charles R. Keys, Des Moines, Iowa.

New York Academy of Science—Mr. Emerson McMillin, New York City; Professor H. P. Cushing, Cleveland, Ohio.

Academy of Natural Sciences of Philadelphia—Doctor Howard Ayers, Cincinnati, Ohio.

Washington Academy of Sciences—*Professor Dayton C. Miller, Cleveland, Ohio; *Doctor Charles F. Marvin, Washington, D. C.

Cincinnati Section of the American Chemical Society—Doctor Lauder W. Jones, Cincinnati, Ohio; Doctor Alfred Springer, Cincinnati, Ohio.

Cincinnati Society of Natural History—Doctor DeLisle Stewart, Cincinnati, Ohio.

Columbus Audobon Society—*Professor J. C. Hambleton, Columbus, Ohio; Miss Lucy Stone, Columbus, Ohio.

Denison Scientific Association—*Doctor George Fitch McKibben, Granville, Ohio; *Mr. Charles W. Henderson, Granville, Ohio.

Wooster University Scientific Club—*Mr. Frank H. McCombs, Wooster, Ohio.

The Cuvier Press Club—Mr. James W. Faulkner, Cincinnati, Ohio.

Association of Ohio Teachers of Mathematics and Science—*Professor S. E. Rasor, Columbus, Ohio.

Ohio State University Scientific Association—Professor Karl D. Swartzel, Columbus, Ohio; *Professor James R. Withrow, Columbus, Ohio.

Oxford Science Club—*Professor J. A. Culler, Oxford, Ohio.

Otterbein Science Club—*Mr. Richard M. Bradfield, Westerville, Ohio.

Baldwin-Wallace Science Seminar—*Professor E. L. Fullmer, Berea, Ohio.

The following members of the old Tyndall Association, so potent in the scientific life of Columbus and Ohio in the Seventies and Eighties, were also present by special invitation:

Mr. H. N. P. Dole, Columbus, Ohio.
Mr. Martin Hensel, Columbus, Ohio.
Mr. Curtis C. Howard, Columbus, Ohio.
Professor William R. Lazenby, Columbus, Ohio.
Doctor C. L. Mees, Terre Haute, Ind.
Doctor T. C. Mendenhall, Ravenna, Ohio.
Doctor Sidney A. Norton, Columbus, Ohio.
Mr. D. E. Williams, Columbus, Ohio.

In the business session the most notable action was the adoption of a constitutional amendment, suggested at the previous annual meeting, by which the date of the annual meeting is changed from Thanksgiving to March or April, the exact date to be fixed by the Executive Committee. By vote of the Academy the next meeting will be held in the spring of 1916.

The Trustees of the Research Fund announced a further gift by Mr. Emerson McMillin, of New York, of $250.00 for the encouragement of the research work of the Academy.

As a result of the suggestions contained in the address by Dr. Mendenhall, on The Relation of the Academy to the State and to the People of the State, a Committee on Legislation was appointed, consisting of Dr. T. C. Mendenhall, Chairman, Prof. F. C. Waite and Prof. Herbert Osborn.

The previous affiliation of the Academy with the Ohio Journal of Science was continued with minor modifications; but the incoming president was instructed to appoint a com-

mittee to confer with the Committee on Legislation as to possibilities of obtaining funds for publication, the Committee to report back to the Academy at its next annual meeting. President Hubbard appointed Prof. J. Warren Smith, Chairman; Prof. Frank Carney, Prof. F. C. Waite, Prof. J. S. Hine and Prof. C. G. Shatzer.

Forty-one new members were elected at the meeting.

The officers and standing committees for 1915-1916 will be as follows:

President—Prof. G. D. Hubbard, Oberlin College.

Vice-President for Zoology—Prof. F. L. Landacre, Ohio State University.

Vice-President for Botany—Prof. M. E. Stickney, Denison Univeristy.

Vice-President for Geology—Prof. T. M. Hills, Ohio State University.

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THE SPECTRA OF SOME HALOGEN COMPOUNDS AND PHENOMENA CONNECTED THEREWITH.*

CHARLES SHEARD and C. S. MORRIS.

A careful search of the literature on the spectra of compounds reveals but few papers of any importance. The first of these is by B. O. Peirce on the "Emission Spectra of Halogen Compounds of Mercury" in the Annalen der Physik, N. F. Vol. 6, 1879. His investigations were carried out using Geissler tubes excited by an induction coil; the tubes with the contained salt were heated by a Bunsen burner. With mercuric and mercurous chlorides he found a band lying between the yellow and the green mercury lines and observed that in the green region the continuous spectrum was filled with many fine, weak lines. The conclusion is drawn that the emission spectra of the two chlorides of mercury under heat are the same, due to the fact that the mercurous chloride dissociates into mercuric chloride and chlorine and the continuous spectrum is therefore due in both cases to the mercuric chloride. The iodide, bromide and chloride compounds of mercury gave continuous bands with their middle points at about 4430, 5000 and 5800 Angstroms respectively.

*Read before the American Physical Society, December, 1915.

In 1897 A. C. Jones published an article (Ann. der Phy. N. E. Vol. 62, page 31) in which he confirmed the results obtained by Peirce and extended the investigations on the bands into the ultraviolet region.

The latest research on the subject is by A. H. Chapman (Physical Review, Second Series, Vol. IV, 1914), who used mercuric iodide, ferric iodide and stannic iodide. In a generalized conclusion he says "that a wide emission band shading off towards the violet and the red is characteristic of the compounds investigated, and that when the absorption spectrum of the compound is available, there seems to be a definite relation existing between the absorption and emission bands. It would seem therefore that the vibrating system responsible for the emission is also effective in producing absorption in solution."

It is the purpose of the investigations here reported upon to extend our present knowledge of the emission spectra of compounds and to determine, if possible, something concerning the nature and structure of the vibrating system or systems responsible for the spectra. It was also hoped to make some comparisons between the emission and absorption spectra of the vapors with certain of the compounds used, but in this latter proposition little success has come. There have arisen, however, in connection with these latter investigations some very interesting phenomena which have either thrown some light on the main problem in hand or furnished a basis for some suggestions as to the nature of the thermions from heated salts.

APPARATUS.

The upper electrode of the apparatus used for examining emission spectra was a brass tube about seven-eights inch in diameter and three inches long, the lower one being a brass tube about three-quarters inch in diameter and eight inches long, with one end tightly sealed with a brass plug. A water cooling jacket was constructed around the upper end of the lower electrode; this served as a screen to prevent direct contact of the gas flame with the rest of the apparatus and, operating as a cooler, preserved the waxed joints and corks. The two metal tubes were connected by a piece of heavy capillary tubing of about 1.3 mm. inside bore. Capillary tubes of

somewhat larger diameter were tried but discarded since the current density of the discharge was not sufficiently great to give an intense spectrum. Too small capillaries could not be used because they readily plugged up with vaporized salt. Rubber stoppers connected the capillary with the remaining parts of the tube.

The form of apparatus used in the attempts made to investigate the absorption spectra of the vapors is discussed later in this paper.

RESULTS.

A Geryck two-cylinder pump was connected to the spectrum tube and a low pressure, varying in different experiments from 1 cm. to 0.1 mm. mercury pressure, maintained. The discharge from the induction coil was then started and without heating the tube the spectrum was examined for lines due to the elements of the compound. In some instances there appeared nothing but the air spectrum,* but in a few cases, as zinc and mercuric iodide, some lines of the elements appeared, indicating that the compound dissociated a little at ordinary temperatures under low pressure. As soon, however, as a little heat was applied the air spectrum began to disappear and a spectrum peculiar to the compound appeared. This remained for some minutes, varying with the compound used, but in general, if further heating was discontinued the air spectrum gradually returned and replaced the spectrum of the compound; this process could be repeated until finally the lower half of the electrode would become red hot without any spectrum of the compound being in evidence. But if the heating of the tube was carried on rapidly the air spectrum was quickly replaced by lines characteristic of the elements of the compound, which in turn gave way to a continuous region or regions with a few lines peculiar to the members of the compound surviving. After heating for some time (usually fifteen to thirty minutes) the spectrum of the compound and its elements was rather quickly replaced by the air spectrum. These changes were so rapid, photographically considered, that few spectrograms have been obtained. The continuous regions

*A careful study was made of the spectrum given by the empty tube both when cold and when heated. Under both conditions a large number of bands, diffuse toward the violet, were found in the region 4861 to 4142 t. m. and are due to nitrogen. Some lines and narrow bands were measured in the red-yellow region, but thus far it has been impossible to identify them.

or bands found in the spectra of the compounds studied are indicated in the following data. The pressure in nearly every case was about 2 mm. of mercury, but it was discovered that a considerable range of pressure (from 0.5 to 10 mms. mercury) had little effect upon the results.

I. Iodides.

Calcium Iodide.

BANDS	REMARKS
6075–5845 (?)	Seemingly continuous but uncertain.
5615–5528	Fairly sharp on red side, diffuse at blue.
5180–5100	" " " " " " "
4830–4787	" " " " " " "
4507–4465	" " " " " " "
4438–4375 (?)	Apparently continuous, but uncertain.

Mercuric Iodide.

BANDS	REMARKS
6072–5845	Sharp towards red, diffuse towards violet.
5605–5535	" " " " " " "
5195–5152	" " " " " " "
4828–4788	" " " " " " "
4506–4470	More or less diffuse at both ends.
4450–4375	" " " " " "

A few prominent lines were measured and identified as follows: 6563 and 4861 due to hydrogen and 5790, 5769, 5461, 4916 and 4358 due to mercury. These lines were present at all stages of operation of the tube. A considerable number of iodine lines made their appearance on first heating the tube.

Zinc Iodide.

Upon the first heating of the zinc iodide the following simple line spectrum of zinc and iodine was obtained; 5781, 5766 and 5448 of iodine, 5182 and 4912 of zinc and in addition 6563 of hydrogen and 4358 of mercury.

With rather low heat the following bands were obtained: 5610-5535; 5195-5116 and 4829-4780. All of these were fairly sharp towards the red and diffuse toward the violet end. A number of sharp lines were also present at this stage of the experiment and a majority of these were measured; 6363, 5894, 4810, 4722, 4680 due to zinc; 6131, 6076, 5961, 5739, 5696, 5628, 5165, 4667, 4645, 4635 due to iodine and the following lines which have thus far not been identified—6235, 6203, 6027, 5937, 5839, 5816, 5119.

Cadmium Iodide.

Heat was applied slowly; numerous spectral lines appeared together with what we concluded to be the same three bands as found in zinc iodide, but as heat was applied the compound quickly ceased to function—due doubtless to rapid vaporization—and the air spectrum returned so quickly with each increase of temperature up to the highest degree attainable that no measurements could be made.

II. Chlorides.

Fused Stannic Chloride.

Low heat gave a continuous region from 5800 to 4400 diffuse at both ends. The following lines were noted when the salt was first heated: 6453, 5799, 5631, 5588, 5563, 5333 and 4525, due to tin and 5460 due to chlorine.

It was found on the initial heating that the tin lines appeared very prominent when the pressure was of the order of a centimeter of mercury, but that these lines disappeared in general and the continuous spectrum named above appeared as the pressure was reduced. With further experimentation this pressure effect disappeared for reasons which will be suggested in the concluding portions of this paper.

Ferric Chloride.

The continuous region, 5900-4800 Angstroms, was not sharply defined at either limit.

It was difficult to get a discharge to pass through the tube containing the ferric chloride when it was heated. The capillary filled readily with a brownish liquid which overflowed the ends of the rubber cork stoppers and operated to form a conducting layer along the surface.

After the disappearance of the air spectrum the characteristic yellow and green lines of mercury and the red and blue lines of hydrogen appeared.* With further heating a continuous region, indeterminate at both ends, occurred from approximately 4800 to 5900. There was no evidence of any iron lines at any period of the experimentation.

*Mercury vapor and hydrogen were present as "impurities" in all these experiments, the mercury coming from the McLeod guage used to measure pressures.

Manganous Chloride.

Low heat gave a continuous region from 5900 to 4450, diffuse at both ends.

The prominent lines were identified as manganese 6017, 4822, 4783 and 4754, in addition to three or four lines belonging to hydrogen and mercury. The spectral examination showed the presence of the base of the compound only; no lines due to chlorine were detected.

III. Bromides.

Calcium Bromide.

Low heat gave a continuous region, 5500 to 4850, shading off at each end.

After the discharge had passed for a little time, but before heating the apparatus, the lines present were measured and identified as those of hydrogen and mercury. This indicates that practically none, if any, of the calcium bromide vaporized and dissociated under low pressure at room temperature.

Mercurous Bromide.

Strong heating gave a continuous region from 5072 to 4912.

Zinc Bromide.

With excessive heating there was obtained a continuous region from 5550 to 5055, neither limit being sharply defined. With the bottom of the lower electrode red hot there was a small, but very intense continuous band, about 100 Angstroms wide, with its center at about 5055, together with a region, much less luminous, which appeared to be continuous from 5550 to 5150.

ABSORPTION SPECTRA OF THE VAPORS.

Chapman (Phys. Rev. 2nd Series, Vol. IV, p. 28, 1914) came to the conclusion that the vibrating system giving the emission spectra of the compounds was also potent in producing absorption in solutions. It is reasonable to suppose that the vibrating system might also persist and preserve its identity in the vaporous state and that the absorption spectrum of the compound should be the complement of the emission spectrum. Several attempts were made to see if such were the case. A tube was constructed, 22 inches in length, with an inside diameter of 1½ inches. The ends were provided with jackets for water cooling. Plano-convex lenses of about 20 cms.

focal length were waxed on to the ends to assist in focusing the light, passing as a parallel beam of light through the tube, upon the slit of the spectrometer. The source of illumination was a Nernst glower. The tube was heated by a long gas burner set between the water cooled jackets. Two chief difficulties arose in the use of the apparatus; one was the condensation of the vapor on the cold glass ends, the other was leakage at high temperatures. Various schemes for improvement were tried, but the time alloted to this portion of the work was too meager to obtain satisfactory results except possibly in one case.

Several trials were made with stannic chloride, a substance which vaporizes readily at a low temperature. Heat was applied rapidly and subsequently a volume of vapor was produced which appeared to cut off all the light coming through the spectroscope, except a broad band in the red end. By making comparison with the emission spectrum for this compound, it seems probable that the absorption and emission spectra are complementary.

The emission spectra, being produced under electrical excitation, are due to ionization set up by some external agency. Since there is no such external source of ionization in the experiments just described, it might be concluded that there would be no ions present and hence, if certain lines of reasoning relative to the production of absorption spectra were followed out, no absorption spectra could be expected. An examination of the inside of the tube, after using mercuric iodide or stannic chloride for example, showed a bright metallic mirror at the water-cooled ends. This proved that dissociation must have occurred and therefore presumably some ionization; a considerable number of experiments by various investigators (Richardson, Willows, Beattie, Schmidt, Sheard et al.) have shown the existence of negative ions of iodine and bromine when their salts have been heated under potential.*

*It is of interest in this connection to cite the experiments of Lenard (Annalen der Physik, 17, page 197, 1905) made with beads of the fused salts of the alkali metals supported upon platinum wires in the Bunsen flame. The emitted light was found to be strongly colored, the color depending upon the metal. An examination of the absorption spectra of the fused salts showed that the color of the transmitted light was complementary to that of the emitted light, as should follow from Kirchhoff's law. The salts were colorless, however, when cold showing that some sort of dissociation resulted from the high temperatures, metallic ions being set free which had the property of absorbing and emitting radiations of the same frequency. In the case of most of the salts examined the color was found to depend upon the metal, i. e., upon the cations; the borates and silicates were marked exceptions, however, the color being due to the anions, the nature of the metal being immaterial.

DEPOSITION OF METALLIC MIRRORS.

When a discharge tube was opened after a spectral examination of a salt it was found that there was a thin metallic deposit covering the inside of the lower electrode in the portion near the water cooled end. It cannot be stated that these were present in the case of every substance investigated; but in the case of mercuric iodide, cadmium iodide, zinc bromide and tin chloride metallic mirrors, almost as brilliant as if polished, were noticed. This shows that considerable dissociation and reduction of the compound occurred under heat and the electrical excitation.

These mirrors, as stated in a preceding paragraph, were also obtained with two compounds which were heated in the apparatus used for investigating absorption spectra. The mirrors obtained from stannic chloride were almost as bright as is the surface of clean mercury. In these experiments no external agent was used except the heat. It is therefore apparent that under heat alone some metallic compounds (at least halogens) are dissociated, the metal being set free. There can have been no reducing agent present, such as would have been the case had the salts been introduced into the flame, unless the residual gas present in the tube could have acted as such agent. This seems improbable in view of the low pressures used.

Some interesting results on "Flame Reactions" have been published recently by Bancroft and Weiser (Journal of Physical Chemistry, Vol. XVIII, 1914) in which they have obtained metallic deposits on cold porcelain introduced into a Bunsen flame which was fed with chlorides and nitrates of copper, cadmium, tin, mercury and silver. These experimenters concluded that "the reducing action of the flame gases is not essential, though at times it may increase the decomposition." With this conclusion the writers of this paper are in accord and feel that the results detailed above establish the legitimacy of this conclusion since the question of flame gases does not enter.

POSSIBLE NATURE OF THE SYSTEMS PRODUCING THE BAND SPECTRA OF THE COMPOUNDS.

In order to present the experimental facts in concise form and to provide a ready reference table in connection with the ensuing discussion the following brief resume of the data obtained on the emission spectra of the compounds is introduced

Continuous Spectral Regions or Bands.

Iodides.

CALCIUM	MERCURIC	ZINC
6075–5845 (?)	6072–5845	
5615–5528	5605–5535	5610–5535
5180–5100	5195–5132	5195–5116
4830–4787	4828–4788	4829–4780
4507–4465	4506–4470	
4438–4360 (?)	4450–4375	

Chlorides		*Bromides*	
Stannic	5800–4400	Calcium	5500–4850
Ferric	5900–4800	Mercurous	5075–4912
Manganous	5900–4450	Zinc	5550–5150

A survey of these results shows that the banded or continuous regions are in general nearly identical amongst the members of any particular group of halogens. In the case of the chlorides and bromides the continuous regions were diffuse or shaded off at each end. In the case of the iodides, however, all the bands except those at 4500-4470 and 4450-4370 were fairly sharp at the longer wave length ends.

It appears that there is some common vibrating or emitting system which is operative in each of these halogen classes. The only common element present, so far as known, in the iodides examined is iodine, and so on for the chlorides and bromides. It seems reasonable to attribute the general similarity of spectra in each of the halogen groups to the halogen members acting directly or in combination as hereinafter suggested. The compounds on initial heating showed, in general, some lines characteristic of the base and of the radical. There is, therefore, some dissociation of the original compounds and production of ions, both positive and negative, some of which to say the least are elemental constituents of the compound designated.

The residues from the various salts were different in color and structure from the compound introduced. For example, the residue from stannic chloride (original salt white in color) came out violet, manganous chloride (original salt slightly pinkish) came out lavender in color. These color effects indicate chemical changes. Examinations of several residues, using the polarizing microscope, were very kindly made by Mr. J. B. Dickson, then of the Department of Chemistry of

the Ohio State University. The following notes are taken from his report:

Hg Br. Metallic mercury unmistakably present. Tiny globules of mercury found under 'scope on surface of lumps of Hg Br.
Cd I_2. Showed presence of metallic cadmium by reflected light.
Zn Br_2. Could get no evidence of presence of free zinc.
Fe_2 Cl_6. Under magnifier, presence of numerous green spots showing existence of $FeCl_2$, or Fe_2Cl_4, (the latter formula being now considered preferable by chemists).
Ca Br_2. All tests showed presence of metallic calcium.
Hg I_2. In this case there was considerable reduction to Hg I.

The writers are disposed therefore to believe that there is dissociation and ionization of some portions of the original compound into its basic and radical components, but that there is also, under the proper conditions, a dissociation of the vaporized salt into a positively charged sub-compound and negatively charged radical. To illustrate, let us take mercuric iodide (Hg I_2). This in part dissociates into Hg_{++} or 2 Hg_+ and $1_=$ or 2 I_-, or positive ions of mercury carrying a single or double charge and negative ions of iodide carrying a single or double charge. In addition there is, as evidenced by the analysis of the residue after heating, a considerable dissociation into Hg I_+ or positively charged mercurous iodide and I_- or negatively charged ions of iodine. It is probable that the banded or continuous spectra arise from the recombination of the oppositely charged mercurous iodide and iodine which are formed from the vaporized, non-dissociated salt present in the capillary portion of the discharge tube, although it is not likely that there is a permanent recombination of mercuric chloride formed. We can say that we have the emission spectrum of the original compound if we admit such a process. That some such process is operative is made plausible by the fact that the banded regions in the case of the iodides have their heads at or near a prominent iodine line. In the case of the chlorides we find extended continuous regions which include the spectrum from the blue to the orange-yellow region. There is no evidence of lines or bands in the red end of the spectrum. The spectrum of chlorine exhibits a richness of lines in the region 5000-4100 Angstroms and a dearth of anything in the red region except the line 6095. The same explanation made for the iodides seems satisfactory here. If stannic chloride dissociates in part into ions of tin and chlorine and in part into positively charged molecules of stannous

chloride and negatively charged ions of chlorine we should expect the experimental results detailed above. Furthermore, none of these banded regions appeared to be associated in any manner with the element making up the base of the salt. This is clearly proven, we believe, by the fact that the banded regions were practically identical in any halogen group irrespective of the base present. Possibly the best illustration is afforded by mercuric iodide in which the lines characteristic of mercury coexisted with the broad bands and were prominent and sharp with no tendency towards broadening or diffuseness.

These experiments also throw light upon the investigations of Professor O. W. Richardson on the specific charge of the ions. In investigating zinc iodide he found that the negative ions were iodine and the positive ions, during the initial stages of heating, correspond most closely to ions of zinc carrying a double charge. We found the spectrum of zinc and iodine present in the early stages of heating, but also found that the zinc lines soon disappeared. In the case of manganous chloride, Richardson found initial values which would correspond to manganese, but with further heating a value of "m" equal to 90 indicating possibly the existence of positively charged Mn Cl. The results of the experiments made by the writers support such conclusions as these. In the case of ferric chloride no spectral evidence of the presence of iron was found at any period of the experimentation, but after sufficient heating a continuous spectrum within the limits of 5900 and 4800 Angstroms was developed. This may indicate, if we follow out the line of argument given in the preceding paragraph, a dissociation into negative ions of chlorine, ($Cl_=$) or ($2Cl_-$) and positively charged sub-compounds of iron and chlorine ($Fe\ Cl_{++}$). If such a positively charged molecular structure existed it would have a value of "m" equal to 45, which would be in accord with Richardson's experimental values of 40.2, 39.3 and 39.8. It is to be stated in this connection, however, that the analysis of the residue from $Fe\ Cl_3$ did not show the existence of such a compound as Fe Cl, but did show the sub-compound $Fe\ Cl_2$. The chemistry of compounds at high temperatures is still somewhat of an unopened book; without doubt there are formed and exist at such temperatures molecular structures or sub-compounds or recombinations of the elements of the original substance of which we know little. The postulation of the

formation of such ionized structures seems to us to be as likely a basis of explanation of some of the values of the specific charge of the ions obtained as the present partially accepted theories of gas ions or ions characteristic of the elements present when salts are heated under potential. The latter premise is apparently correct in many instances, but the assumption of an impurity, such as sodium, when the value of "m" lies near 23, or of potassium when the value of "m" lies near 39, seems a trifle far fetched in some instances.

CONCLUSIONS.

1. The halogen compounds investigated exhibit broad bands or continuous spectra which are probably due to the formation of positively charged sub-compounds and subsequent recombination with the negatively charged ions characteristic of the radical of the salt.

2. The bands and continuous spectra obtained are in general agreement as to number, position and character for the compounds of any specified haloid investigated. Continuous spectra are exhibited by the chlorides and bromides and several bands by the iodides.

3. The radical and not the basic element of the compound investigated appears to be the essential controlling factor.

4. There is present in the initial stages of heating of several of the compounds a dissociation into positive and negative ions spectrally determined to be the two components of the original compound.

5. There is found in the discharge tube in nearly every case a metallic deposit or mirror of the base of the salt investigated. These deposits were also found when no external ionizing agent other than heat was employed. These experiments settle in the negative the question as to whether or not the reducing action of the flame gases of a Bunsen burner is necessary for the deposition of the metallic constituent of a salt.

6. The evidence points to the conclusion that there is an absorption spectrum of the vapor of the compound which corresponds to its emission spectrum.

Ohio State University.

SUNFISH NESTS OF BEIMILLER'S COVE.*

F. H. KRECKER.

During the night of July 4-5, 1915, a strong southwest wind drove the water of Sandusky Bay out into Lake Erie in such quantities that it receded thirty feet from the shore line in what is known as Beimiller's Cove. This decided drop in the water level brought to my attention some nests of the sunfish, Eupomotis gibbosus, which circumstance suggested a study of the conditions under which the fish of this region breed. As is well known many of the fishes of the Great Lakes choose the shallow bays and coves for breeding places. An investigation of these localities is of some importance, since with the present rapid occupation of these shores by man and their consequent alteration, the neighboring waters lose much of their value for breeding purposes. The finding of suitable nesting places must be presenting a greater problem to the fish each year.

The observations recorded in this article have to do with conditions in Beimiller's Cove alone and are therefore not sufficiently extensive to draw conclusions regarding the general situation. And even what has been recorded from this cove is to be looked upon chiefly as a preliminary study. There are some points of interest, however, worth noting. It is hoped that further and more far reaching observations to be undertaken in the future may throw considerable light upon these questions.

Beimiller's Cove is an indentation in the sandy peninsula known as Cedar Point, which stretches across the eastern end of Sandusky Bay from the southeast and separates it from Lake Erie. The cove lies on a line running southeast and northwest and is about half a mile long and one-third of a mile wide. At its inner end there empties a sewage canal. The depth of water varies from less than a foot at the inner end and along the sides to six or eight feet in the center and at the mouth of the cove. The bottom is covered with a luxuriant growth of aquatic plants, such as Myriophyllum. Along the shores are reeds, particularly Scirpus americanus. The bottom and shores

*Contribution from the Dept. of Zoology and Entomology, Ohio State University, No. 45.

toward the inner end are mucky. Water lillies are abundant here. The western shore is thickly covered with reeds, at places there are marsh conditions and nearly everywhere there is a deposit of dead vegetation. Where this vegetation is absent a sandy or pebbly bottom is exposed. The bottom along three-fourths of the eastern shore for a distance of fifteen

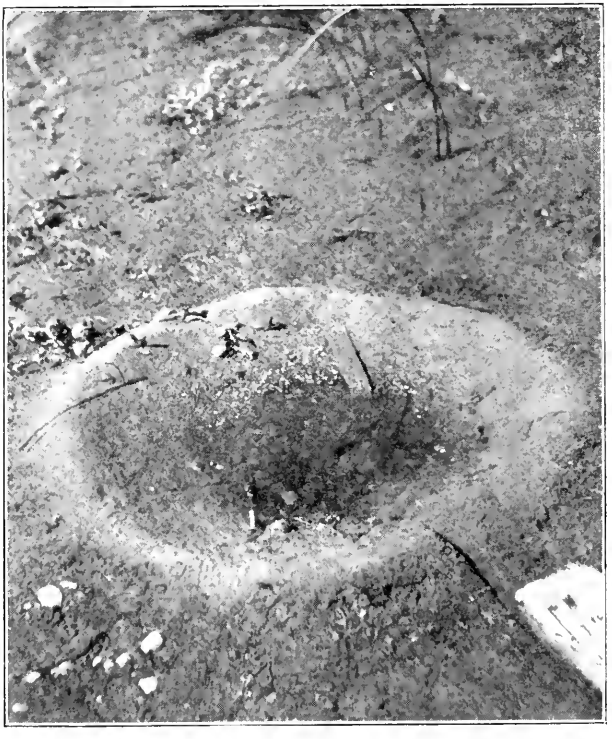

Figure 1. Large nest completely exposed. Some water still covers bottom of nest. Darker spot in center of this marks area within which eggs lie.

to twenty-feet out from the shore line is sandy and pebbly and is sparsely covered with vegetation. The difference between the eastern and the western shore is due partly to the influence of winds and currents which tend to pile up debris on the western side.

The observations on the nests were made at intervals of about a week between July 5 and July 27, 1915. Within this period the total number of nests counted was 419. These

were divided into two distinct types, large nests and small nests. I shall describe the larger type first.

The large nests were found on the sandy stretches of bottom. A good conception of their appearance can be gained from the photographs shown in Figures 1 and 2. They are crater like depressions in the sand at the bottom of which were coarse sand or pebbles and sometimes a large solid object, such as a

Figure 2. Three large nests exposed on characteristic bottom. Rim of nest in center adjoins that of a nest to the left.

half of a clam shell or a piece of wood that had happened to be buried at the point selected. The depressions were sometimes circular but more often oval. The length of the largest nests measured was thirty-six inches across the top and their width twenty-seven inches. Some of the nests were twenty-five inches by thirty inches and a few were as small as eighteen by twenty inches. The depth of the nests averaged three inches. This, however, depended upon the amount of sand

that had to be scooped out to obtain the proper bottom. The eggs lie in the apex of the depression. They are approximately one millimeter in diameter and they blend so well in color with the sand as to make them rather hard to detect. The large nests were confined to a fairly well defined zone which began about ten feet from the water's edge and extended outward to a line between eighteen and twenty feet from shore. Most of them were in water which was from eleven to fourteen inches deep. A few were in fifteen inches of water.

In describing the location of the nests reference will be made to the outline sketch of the cove shown in Figure 4. The larger rings represent the large nests and the smaller rings indicate the small nests. The letters are for convenience in description and are explained in the text.

On July 5, a group of large nests was found on the eastern side opposite the point A on a sandy bottom with some vegetation. This group lay approximately fifteen feet from shore on the border line of the mucky region at the inner end of the cove. Some of these nests are shown in Figure 3. Between A and the Lake Laboratory landing (L) fifteen other nests were scattered. These were likewise on a sandy bottom and for the most part lay singly. Three of these are to be seen in Figure 2. There were also some large nests near the south side of the landing, but they were not counted at this time.

From July 12 to 16, a survey was made of the whole eastern shore. On this side all the nests were in the strip of sandy and pebbly bottom, previously mentioned, which was only sparsely covered with vegetation and extended for twenty-five to thirty feet from shore. The conditions were in general like those shown in Figure 2. Between the above dates 138 nests were counted from the landing to the point H, a distance of about a hundred and fifty yards. No nests were found beyond H.

By July 27 there were no occupied nests north of the Lake Laboratory landing and most of the nests previously seen south of this were no longer in use. However, there were some fresh nests among the old ones near H and others were now found as far down as S, at which point there are the remains of an old scow. The total number of nests for the region L to S was thirty. Of these eleven were between H and S. From S to M there was a firm, sandy bottom, but there were no nests

here. In the region M there was a mucky bottom. From M to P the bottom was again favorable. About K there were three scattered nests. In the region of N there were sixteen nests. These nests were in eighteen inches of water.

On the western side there was no continuous stretch of open sandy bottom such as was found on the opposite side. The belt of reeds extended out quite a distance, in some spots ten to fifteen and twenty feet, and at these points other aquatic

Figure 3. Group of the nests at A (Fig. 4), bottom becoming mucky.

plants grew from the cove side up to the reed line, thus isolating patches of open bottom.

The survey of the western shore was made between July 12 and 19. In the indentation at D there was a good growth of water lillies, the shores were marshy, the bottom muddy and the water frequently so tainted with sewage as to be greasy. There were no nests here. Along the short stretch *a*, there was a firm, sandy and open bottom. Here seven nests were found. The inlet B had no nests; its character was similar to that of D. The points *a*, *b*, *c*, *d*, *e*, *f*, *g*, *h*, *i*, *j*, *k* had a sandy and comparatively open bottom.

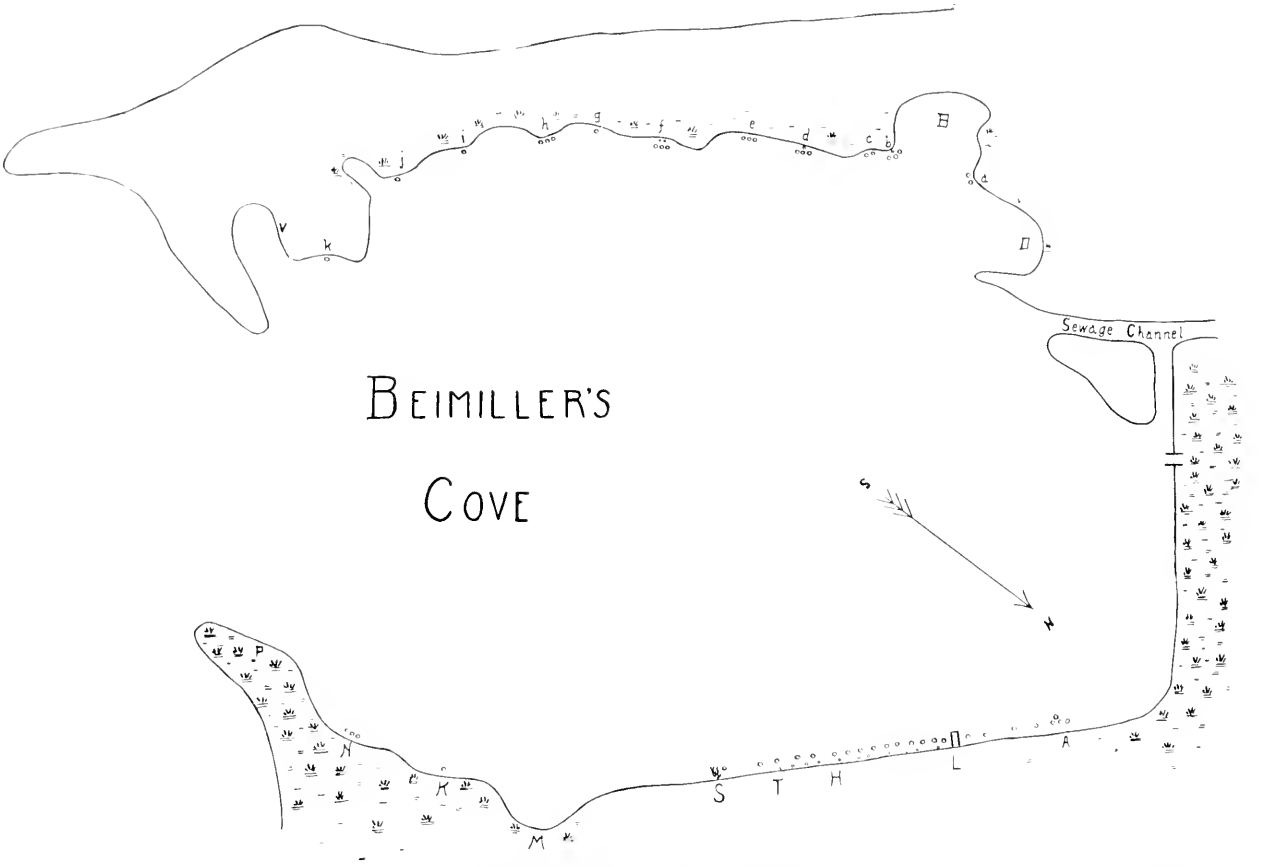

Figure 1. Large rings represent location of large nests, small rings indicate small nests. L is the Lake Laboratory landing. For other points see text.

The following table gives the number of nests at each point:

	LARGE NESTS	SMALL NESTS
a.	7	
b.	18	2
c.	10	
d.	17	1
e.	14	
f.	14	5
g.	4	
h.	12	
i.	3	
j.	3	
k.	1	
Total.	103	8

The nests at *g* were among reeds. At *v* the bottom was clear and sandy and appeared to be ideal for nests but none was found. The total number of large nests, including those on both shores, was 290.

The other type of nests, the small nests, were approximately circular and had an averaged diameter of seven inches. Practically all of them were on the eastern side. With two exceptions they were found at a distance not greater than six feet from the shore, most of them within three or four feet of it. The exceptions were two widely separated nests which were fifteen feet from the shore line. In the zone of more usual occurrence there was a pebbly bottom and a fringe of reeds, largely Scirpus americanus. The nests were made on the pebbles among the reeds. A photograph of this type is shown in Figure 5 between the arrows.

The depressions in many cases were so shallow that their outlines could frequently only be determined by the fact that the pebbles had been fanned clean. The roots of reeds were often at one side of a nest but since the reeds grew close together this could not well be avoided. They were never found in more than seven inches of water, barring the exceptions noted, and some were in barely enough water to cover them.

During the period July 12 to 16, 105 of these small nests were found on the eastern shore between the points L and H. By July 27 they were found as far down as the point T. On this date sixteen of them were counted between H and T. Although I made careful search, I could discover them no where else on the eastern side. In the survey of the western shore made from July 12 to 19, only eight small nests were found. Two of them were located at the point *b*, one at *d* and

five at *f*. The total number of small nests, including those on both shores, was 129.

In a general consideration of the sunfish nests in the cove several features should be noted. The type of bottom which appears to be most suitable for nest building is one composed of sand, or sand and pebbles, with little or no vegetation. This is borne out by the fact that on the sandy and open bottom of the

Figure 5. Small nest, between the arrows, in a typical location. Photograph taken through the water.

eastern shore there was a total of 308 nests whereas along the more overgrown western shore there were only 111 nests. Also on comparing the eastern with the western shore, it will be seen that in each case the nests were almost exclusively where the bottom was of the character described. On the western side suitable areas were found from *a* to *k* and on the eastern side there was an almost unbroken stretch from A to P.

However, the character of the bottom does not appear to be the only determining factor in nest location. The stretch

of shore at *a* is apparently as favorable as that along the most of the eastern side, considerably more so than much on the western side, which was occupied, and yet in this stretch there were no nests. There is also a similar strip on the eastern side between S and M, which was unoccupied. In fact, taken as a whole, the eastern side presents more favorable surroundings than does the western side and all the nests on the latter shore could have been accommodated on the opposite one. These circumstances suggest that other factors in addition to the character of the bottom aid in determining the matter of location.

What these other influences are is not yet clear. An element of chance with regard to the shore the fishes follow as they enter the cove may enter into the choice. If anything approximating suitable conditions are found on the shore followed they probably nest without seeking farther.

Another factor which apparently has some bearing is the proximity of other nests. This is to be gathered from the fact that there is very clearly a tendency to build the nests in groups independently of any influence which restricted area may have in this direction. The grouping of nests on the western shore can be credited in part to restricted surroundings. However, on the eastern side where there was plenty of space to permit a wide distribution, there was at certain points a decided grouping. This applies to both types although it was more generally true of the small type. Three or four large nests were frequently found rather close together and in some cases they were so near each other that their rims touched. Two such nests are to be seen in Figure 2. One of the most extensive groups of large nests was found north of the laboratory landing at A. A part of this group is shown in Figure 3. The small nests nearly always occurred in groups. I have a record of only ten solitary small nests. They were frequently placed in triangular groups of three, the members of a group lying as close together as they well could. In other instances there were as many as five or six nests within a short distance of each other. There would then be an interval without nests, although apparently suitable for the purpose, followed by another group.

One other matter of interest with regard to location is the fact, already pointed out, that each type of nest was confined to a distinct zone. This condition was well shown on the

eastern side, where there was a distance of four feet between the two zones. The zone of large nests began ten feet from shore, whereas the small nest zone ended six feet from the water's edge. I have no data at hand that afford an entirely satisfactory explanation of this separation. The position of the small nests along the edge of the water is hardly favorable for the hatching of eggs since the constant fluctuation in water level frequently causes some of the nests to be uncovered. Occasionally they are exposed long enough to destroy the eggs. The fish guarding the small nests were not as large as those on the larger nests and it is possible that they were unequal to the task of forming nests in the deeper sand farther from shore. It is possible also that they sought the shallow water to escape enemies. However, I saw nothing to indicate that they were forced to this location by the larger individuals.

A condition of considerable importance from the standpoint of the cove as a breeding place is that it is being contaminated with sewage. Since an open sandy bottom is apparently such an important factor in nesting conditions its obliteration is certain to have harmful results. To a certain extent the sewage is having this effect. It is being deposited over the inner end of the cove and especially over that part about the mouth of the sewage canal. However the direct effects of the sewage deposit are probably not as great as are its indirect effects. The latter are brought to bear through the fertilizing action of the sewage upon the plants that take possession of the bottom. The growth of the plants in the cove is luxuriant even for a region in which aquatic plants are abundant. The sewage also has a harmful influence through its vitiating effect upon the water. The situation is such that this effect is confined mainly to the western side, and probably as yet, it is no great factor even here, since patches of sand within the contaminated are occupied, as for example at *a*. Nevertheless the results are disastrous where the sewage concentration is great, as it is near the mouth of the canal. Its influence here may be estimated from the fact that some carp kept in a "live box" near the mouth of the canal died; and carp are not usually credited with seeking the purest water. If the sewage continues to be emptied into the cove, as it doubtless will be, a marked influence upon the fish visiting the locality will probably be noticeable within a few years.

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HEXAGON NOTATION.

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(1) Salmon, in the "Notes" at the end of his Conic Sections designates by $\left\{\begin{matrix}ab\\de\end{matrix}\right\}$ the point of intersection of the lines ab, de; by $\left\{\begin{matrix}ab,\ cd,\ ef\\de,\ fa,\ bc\end{matrix}\right\}$ the Pascal line which contains the three points indicated by the vertical columns; and by the following a g-point and an h-point, respectively:

$$\left\{\begin{matrix}ab,\ de,\ cf,\\cd,\ fa,\ be,\\ef,\ bc,\ ad,\end{matrix}\right\}\ (g); \qquad \left\{\begin{matrix}ab,\ ce,\ df\\cd,\ bf,\ ae\\ef,\ ac,\ bd\end{matrix}\right\}\ (h)$$

The lines in (g) (h), taken in pairs, indicate the Pascal lines which meet in a point, *but the lines do not give the hexagons.* In (h) only two Pascals are indicated, since ce, ac, do not meet on the Pascal line, nor do df and bd.

To get the hexagon indicated by the first and second lines of (g) start with ab of the first line; look up the letter with b in the second line, giving abe: then the letter with e in the first line, abed; then that with d in the second line, abedc; then that with f in the first line, getting, finally, abedcf.

Treating the pairs of lines in (g), (h) in this way we get, rather tediously, the hexagons:

$$\left\{\begin{matrix}abedcf\\cdafeb\\efcbad\end{matrix}\right\}\ (g); \qquad \left\{\begin{matrix}abfdce\\cdbfea\\efdbac\end{matrix}\right\}\ (h)$$

(2) I give here a notation *which indicates the hexagons by horizontal lines, as also their Pascal lines, when horizontal lines are taken in pairs.* The points (g), (h) above are:

$$\left\{\begin{matrix}ab,\ ed,\ cf\\cd,\ af,\ eb\\ef,\ cb,\ ad\end{matrix}\right\}\ \begin{matrix}(1)\\(2)\ (g');\\(3)\end{matrix} \qquad \left\{\begin{matrix}ab,\ fd,\ ce\\dc,\ ae,\ fb\\ef,\ db,\ ac\\ba,\ ec,\ df\end{matrix}\right\}\ \begin{matrix}(1)\\(2)\ (h')\\(3)\\(1').\end{matrix}$$

In (g′) line (2) is formed from line (1) by writing under each segment of (1) its opposite segment in (1), *reversing the hexagon order of letters in (1):* (3) from (2) as (2) from (1); (1) and (2) give the Pascal line of (1); (2) and (3) that of (2); (3), (1) that of (3).

In (g′) there is also cyclic permutation of the initial letters of the segments in one direction (to the right) and of the final letters in the other direction (to the left). This offers the easiest way of writing (g′).

In (h′), line (2) is formed from line (1) by setting under each segment of (1) its opposite segment, *retaining the hexagon order of letters in (1) in one column* (here the first) *and reversing it in the other two;* (3) from (2) as (2) from (1); (1′) from (3) as (3) from (2); (1′) is (1). The lines (1) and (2) give the Pascal of (1); (2), (3) that of (2); (3), (1′) that of (3).

(3) When only the hexagons which enter into (g) and (h) are desired, they may be written thus:

$$\left\{\begin{matrix}\text{a b c d e f}\\ \text{a f c b e d}\\ \text{a d c f e b}\end{matrix}\right\}\begin{matrix}(1)\\(2)\\(3)\end{matrix}\ (g'');\qquad \left\{\begin{matrix}\text{c e a, b f d}\\ \text{e a c, d b f}\\ \text{a c e, f d b}\end{matrix}\right\}\begin{matrix}(1)\\(2)\\(3)\end{matrix}\ (h'')$$

In (g″) one set of alternate letters (here a, c, e) is held fixed; the other set permuted cyclically (in either direction).

In (h″), line (1) is divided into two groups by a comma. Each group is permuted cyclically, the one in the opposite direction of the other. If the hexagons in (h″) are to indicate the same point as (h′), set astride the comma the segment of the first line of (h) in the column which was to hold the hexagon order (here ab) in (h″).

These notations lend themselves, as will be seen in the following, most readily to determine the whole geometry of the hexagon configuration.

(4) The g-point of any hexagon is the center of perspective of its two triangles of alternate sides, the axis of perspective being the Pascal line of the hexagon.

To write the g-point of any hexagon, interchange any pair of its alternate letters for the first line and proceed as in (g′) or (g″).

For a b c d e f (interchanging c and e) it is:

$$\left\{\begin{matrix}\text{ab, ed, cf}\\ \text{cd, af, eb}\\ \text{ef, cb, ad}\end{matrix}\right\}\ (g_1)\qquad \text{or}\qquad \left\{\begin{matrix}\text{a b c d c f}\\ \text{a f c b c d}\\ \text{a d c f c b}\end{matrix}\right\}\ (g_2).$$

(5) *The conjugate g-point of any given g-point*

The g-point of any hexagon of a g-point is one and the same g-point (the conjugate g-point).

For (g_1) of (4) it is g'_1 or g'_2 following:

$$\left\{\begin{matrix}\text{ab, cd, ef}\\ \text{ed, af, cb}\\ \text{cf, eb, ad}\end{matrix}\right\}(g'_1); \qquad \left\{\begin{matrix}\text{a b c d e f}\\ \text{a f c b e d}\\ \text{a d c f e b}\end{matrix}\right\}(g'_2).$$

Of a pair of conjugate g-points, one is inside the conic; the other outside; the line joining them is divided harmonically by the conic (Steiner).

The g-point *on* the Pascal of any hexagon is conjugate to that *of* the hexagon.

(6) *To find three hexagons for which a given g-point is the g-point.*

Write the conjugate g-point.

(7) *The two ordinary h-points of any hexagon and how to write them.* For any hexagon, as a b c d e f (1), write the triangle of alternate letters:

ac, ce, ea.

Write under each letter its opposite letter in (1) giving,

$$\left\{\begin{matrix}\text{ac, ce, ea}\\ \text{df, fb, bd}\end{matrix}\right\}(T).$$

The triangle, T, whose vertices are indicated by vertical columns here, is in perspective with each of the triangles of alternate sides of (1), giving for (1) two h-points. (T) may be called the Pascal triangle of the given hexagon.

To write the h-points of (1), write (1) forward and backwards as in,

a b c d e f (1)
a f e d c b (2)

Group the alternate letters of (1), (2) in two groups, in opposite directions, giving for (1) and (2) respectively:

a c e, f d b; a e c, b d f,

as the first lines of the desired h-points. Then complete as in section (3) giving:

$$\left\{\begin{matrix}\text{ace, fdb}\\ \text{cea, bfd}\\ \text{eac, dbf}\end{matrix}\right\}(h_1); \qquad \left\{\begin{matrix}\text{aec, bdf}\\ \text{eca, fbd}\\ \text{cae, dfb}\end{matrix}\right\}(h_2).$$

We call these *the two ordinary h-points of the corresponding hexagon* (1), to distinguish them from the unique *h-point of the same hexagon* (see section (9)).

(8) *The two ordinary hexagons of any h-point.*

While the hexagons of a g-point give only one g-point, they give, not six h-points, but only three.

Any two hexagons related as

ab, cd, ef
ba, dc, fe

will have one of their ordinary h-points in common. This relation is the same as,

ab, cd, ef
ab, ef, cd

The hexagons of any g-point show this sort of relation in pairs.

For a given h-point, like

$$\left\{\begin{matrix}\text{ace, fdb}\\ \text{cea, bfd}\\ \text{eac, dbf}\end{matrix}\right\} \text{(C)}$$

its two ordinary hexagons are given by reading the first and last letters of each line, in regular order, down the lines (or last and first) giving,

ab, cd, ef
ba, dc, fe;

also straddling the comma.

In the notation like h′ of Section (2), the two hexagons are gotten by reading zig-zag, the column which retained the hexagon order. For h′, it was the first column, giving ab, cd, ef and ba, dc, fe.

(9) *The unique h-point of any hexagon.*

In any h-point, as (C) in (8), there are only nine of the fifteen hexagon lines. In (C) they are ac, ce, ef, fd, db, ba, ea, bf, cd.

The remaining six lines form a hexagon related thus uniquely to the given h-point.

To write the first line of the unique h-point of any hexagon, a b c d e f (1), write the alternate letters in two groups; ace, bfd; the second group begins with the letter adjacent the initial letter of the first group on the side in the direction of the first grouping and is taken in the direction opposite the first.

This gives for a b c d e f, the unique h-point.

$$\left\{\begin{matrix}\text{ace, bfd}\\ \text{cea, dbf}\\ \text{eac, fdb}\end{matrix}\right\} \text{(D)}$$

The geometric relation of a hexagon and its unique h-point will appear later. (See section 40).

(10) *To write the unique hexagon of any given h-point.*

Set the fourth letter of *any line* between the first and second; the sixth between the second and third,

That for (C) is a f c b e d;
That for (D) is a b c d e f.

(11) *Relation between the unique hexagon of an h-point and its two ordinary hexagons.*

The two ordinary hexagons of (D) in (9) are, by (8),

ad, cf, eb
da, fc, be

and the unique hexagon is, in (10), a b c d e f, but these three hexagons are those of the g-point.

$$\left\{\begin{matrix}\text{a b c d e f}\\ \text{a f c b e d}\\ \text{a d c f e b}\end{matrix}\right\}$$

(12) *To write a g-point and two h-points on a straight line.*

It follows at once from the definition of these points that the g-point and the two ordinary h-points of any hexagon are on a straight line.

(13) *To write a g-point and three h-points on a line.* (Salmon's G-line).

The hexagons of any g-point will give g', h_1, h_2 on a line; also g', h_2, h_3 on a line; also g', h_3, h_1 (See sec. (8), (11), (12)).

Therefore, g', h_1, h_2, h_3 are on a line, where g' is the conjugate g-point of the given g-point. (See (5)).

Therefore, *the g-point and three unique h-points of the hexagon of a g-point are collinear.* And what is the same thing and the same line, *the g-point and three pairs of ordinary h-points of the hexagon of a g-point are a g-point and three h-points on a line.*

(14) *The number of g-points.*

In forming g' in section (2) we reversed the hexagon order of segments in each column. This can be done in only one way.

Therefore each hexagon enters into only one g-point. Therefore twenty g-points.

(15) *The number of h-points, and how to write three h-points on any Pascal line.*

In forming (h′) of section (2) we held the hexagon order in one column and reversed in two. This can be done in three ways, therefore each hexagon enters into three h-points, therefore, three times as many h-points as g-points. Therefore sixty h-points.

This is also shown in the notation of section (3), since the line (1) can be grouped in three ways as indicated.

To write three h-points on a Pascal line, proceed as in h′ of (2), retaining the hexagon order in columns 1, 2, 3, in order; or, if using the notation in (3), use as initial lines, abc, def; bcd, efa; cde, fab.

(16) *The number of G-lines.*

By (13) each g-point gives a G-line through its conjugate g-point.

Therefore, twenty G-lines.

(17) *Given a g-point to write the three h-points on a G-line with it.*

Write the conjugate g-point (5) and the three h-points unique to its hexagons ((9), (13)). Also on any Pascal line there is one g-point and three h-points, ((14, (15)).

(18) *Given one h-point of a G-line to write the g-point and two remaining h-points.*

Write the hexagon unique (10) to the given h-point; then the two hexagons which enter with this hexagon into a g-point ((2) or (3)); then their two unique h-points, and the conjugate g-point. Thus, through any h-point goes only one g-line.

(19) *To write three g-points on a line.*

Write the g-points of the hexagons of any h-point. The triangles of alternate sides of the hexagons of an h-point are but three in perspective in pairs at three g-points (4), with axes of perspective concurrent in the h-point; therefore the three centers of perspective are collinear.

(20) *To write three lines of three g-points each, with a g-point in common.*

Write the three lines of g-points of three h-points *on any Pascal line*, (15). The g-point in common to the three lines is the g-point conjugate to that on the common Pascal line. ((19) and (5)).

(21) *The nine h-points on three Pascal lines which meet in a g-point establish the same three lines noted in (20).* (See (11)).

If the g-point lines in (20) are,

$$g', g_2, g_3$$
$$g', g_4, g_5$$
$$g', g_6, g_7$$

those noted in (21) will be (in addition), easily tested by writing them in full:

$$g', g_2, g_8;$$
$$g', g_4, g_9;$$
$$g', g_6, g_{10};$$
$$g', g_3, g_8;$$
$$g', g_5, g_9;$$
$$g', g_7, g_{10};$$

which are the same lines as in (20), since two points fix a line. Here g' is the conjugate of the g-point of the three given Pascal lines.

(22) By (21) *the nine h-points on three Pascal lines meeting at a g-point establish three lines of four g-points each through the conjugate g-point.* (Salmon's I-lines).

These lines are established by different sets of three points, *the conjugate g-point always included.*

(23) *Through the g-point where three Pascal lines meet goes also one G-line (17), with three h-points. These three h-points establish the same I-lines noted in (22), by sets of three points, the conjugate g-point always excluded.*

The lines will be (if written out):

$$g_2, g_3, g_8;$$
$$g_4, g_5, g_9;$$
$$g_5, g_7, g_{10}.$$

(24) By (22 and (23) it follows that the twelve h-points of the four lines of h-points (three Pascal lines and one G-line) passing through a g-point establish three I-lines of four g-points each through the conjugate g-point.

(25) By (24) there are fifteen I-lines.

(26) By (24) there must be four h-points grouped about a g-point (one on each of its Pascal lines and one on its G-line) which establish a single line of four g-points through the conjugate g-point; and for each g-point three such h-point quadrangles.

(27) To write such a quadrangle of h-points as noted in (26),

a b c, d e f (1)
a c e, b d f (2)
a e d, c b f (3)
a d b, e c f (4)

(1), (2), (3), (4) form the initial lines, properly grouped for such a quadrangle. Line (2) is formed from (1) by taking alternate letters, in regular order, in two groups as indicated; (3) from (2) as (2) from (1); (4) from (3) as (3) from (2). The h-points with (1), (2), (3), (4) as initial lines are:

$$\left\{\begin{matrix}\text{abc, def}\\ \text{bca, fde}\\ \text{cab, efd}\end{matrix}\right\} (h_1); \qquad \left\{\begin{matrix}\text{ace, bdf}\\ \text{cea, fbd}\\ \text{eac, dfb}\end{matrix}\right\} (h_2).$$

$$\left\{\begin{matrix}\text{aed, cbf}\\ \text{eda, fcb}\\ \text{dae, bfc}\end{matrix}\right\} (h_3); \qquad \left\{\begin{matrix}\text{adb, ecf}\\ \text{dba, fec}\\ \text{bad, cfe}\end{matrix}\right\} (h_4).$$

Now write by 4, the g-points of the hexagons in h_1, h_2, h_3, h_4, and they will be respectively:

$g_1, g_2, g_3;$
$g_3, g_4, g_2;$
$g_2, g_1, g_4;$
$g_4, g_3, g_1.$

$\therefore$ g_1, g_2, g_3 and g_4 are collinear.

(28) *To write three such quadrangles of h-points* (as in 27) *grouped about the g-point containing abcdef* (1).

Group (1) in the three ways:

abc, def; bcd, efa; cde, fab,

and form from each grouping a set as in (27).

(29) *The three g-points conjugate to those on the Pascals of an h-point are collinear.*

They are conjugates by 5 and collinear by 19.

(30) *The three g-points of the hexagons of an h-point are collinear with the g-point on the Pascal of the hexagon, unique to the h-point.*

In 27, (h_1) gave the g-points g_1, g_2, g_3.

The second hexagon in h_2 gives:

$$\left\{\begin{matrix}\text{c e b f a d}\\ \text{c f b d a e}\\ \text{c d b e a f}\end{matrix}\right\} (g_4).$$

where the middle line is the hexagon unique to h_1 (10).

(31) *To write four g-points on an I-line.*

Use (30), which shows there are 15 I-lines.

(32) *The four g-points of an I-line are on the Pascals of the hexagons unique to the four h-points of the corresponding h-point quadrangles as given in (27); as also on the Pascals of the hexagons ordinary.*

The hexagons unique to the four h-points in (27) are:

$$\left.\begin{matrix} \text{a d b f c e (1)} \\ \text{a b c f e d (2)} \\ \text{a c e f d b (3)} \\ \text{a e d f b c (4)} \end{matrix}\right\} \text{(A)}.$$

and (1) is in g_4; (2) in g_1; (3) in g_3; (4) in g_4.

[Note that line (2) of (A) is formed from line (1), by writing first the alternate letters of (1), abc; then the second set of alternate letters of (1), beginning with the fourth letter from the initial letter of the first set, the second set being taken in the same direction as the first set. The set is unique].

By (11) the same g-points fixed by (A) are also on the Pascals of the hexagons ordinary, one set of which for the h-points of (27) is:

$$\left.\begin{matrix} \text{af, be, cd (I)} \\ \text{af, cd, eb (II)} \\ \text{af, eb, dc (III)} \\ \text{af, dc, be (IV)} \end{matrix}\right\} \text{(B)}.$$

(33) Set (A) of (32) shows there are 15 I-lines, since any line of (A) uniquely determines all the rest. There are thus only 15 such complete quadrilaterals as (A).

In (A) there are 4 Pascal lines meeting in six Pascal points, and the triangle of any three of the lines is the Pascal triangle (7) of the fourth hexagon. These fifteen quadrilaterals determine the most important features of the hexagon geometry. (See second paper.)

(34) *To write three I-lines through any g-point.*

Form from each line of the g-point a group like (A) of (32), for the initial lines of the four g-points on each of the three I-lines. Therefore through each g-point pass three I-lines of four g-points each.

For the g-point $\left.\begin{matrix} \text{a b c d e f} \\ \text{a f c b e d} \\ \text{a d c f e b} \end{matrix}\right\} (g_1)$.

The three lines of g-points are (by initial lines)

$$\left\{\begin{matrix} a\ b\ c\ d\ e\ f\ (g_1) \\ a\ c\ e\ d\ f\ b\ (g_2) \\ a\ e\ f\ d\ b\ c\ (g_3) \\ a\ f\ b\ d\ c\ e\ (g_4) \end{matrix}\right\};\quad \left\{\begin{matrix} a\ f\ c\ b\ e\ d\ (g_1) \\ a\ c\ e\ b\ d\ f\ (g_5) \\ a\ e\ d\ b\ f\ c\ (g_6) \\ a\ d\ f\ b\ c\ e\ (g_7) \end{matrix}\right\};\quad \left\{\begin{matrix} a\ d\ c\ f\ e\ b\ (g_1) \\ a\ c\ e\ f\ b\ d\ (g_8) \\ a\ e\ b\ f\ d\ c\ (g_9) \\ a\ b\ d\ f\ c\ e\ (g_{10}) \end{matrix}\right\}$$

In a set of g-points like the ten above no two are conjugate to each other.

(35) *To write two sets of conjugate g-points, of ten points in each set, each set having a point in it conjugate to a point in the other set.*

Treat two conjugate g-points as was (g_1) of (34).

(36) *To write four G-lines concurrent in an i-point.* (Salmon's notation).

Write four g-points on a line (by (31) or (32)); then the three h-points unique to the hexagons of each of the collinear g-points. This will give four lines containing three h-points each, one line passing through each of the g-points conjugate to the four collinear g-points.

These four g-lines are concurrent in an i-point.

The triangles of alternate sides of the hexagons of a g-point are but three (A, B, C). Their Pascal triangles (7) are three (P_1, P_2, P_3). By (4) A, B, C are in perspective at the conjugate g-point (g_1); by 7 and 8, A, P_1, P_2 are in perspective at h_1; B, P_2, P_3 at h_2; C, P_3, P_1 at h_3. Therefore, g′, h_1, h_2, h_3 are collinear (a G-line). It follows easily that for four collinear g-points, the resulting four G-lines are concurrent.

(37) *There are three i-points on each G-line.*

Through each g-point there are three I-lines of four g-points each (34). Each gives an i-point on the G-line through the conjugate g-point, as in (36).

(38) *The three h-points unique to the hexagons of an h-point are all on the Pascal line of the hexagon unique to the given h-point.*

The h-point unique to a b c d e f (1) is, by (9),

$$\left\{\begin{matrix} ace,\ bfd\ (2) \\ cea,\ dbf\ (3) \\ eac,\ fdb\ (4) \end{matrix}\right\}\ (h_1).$$

The three h-points unique to (2), (3), (4) are:

$$\left\{\begin{matrix}\text{aef, cdb}\\ \text{efa, bcd}\\ \text{fae, dbc}\end{matrix}\right\}\ \begin{matrix}(5)\\ (1)\ (h_2)\\ (6)\end{matrix}\ ;\quad \left\{\begin{matrix}\text{cab, efd}\\ \text{abc, def}\\ \text{bca, fde}\end{matrix}\right\}\ \begin{matrix}(7)\\ (1)\ (h_3)\\ (8)\end{matrix}\ ;\quad \left\{\begin{matrix}\text{ecd, abf}\\ \text{cde, fab}\\ \text{dec, bfa}\end{matrix}\right\}\ \begin{matrix}(9)\\ (1)\ (h_4)\\ (10)\end{matrix}$$

These all contain (1).

(39) *The ten hexagons in (38) are a Veronese group.*

In such a group there are ten h-points, on ten Pascal lines, three h-points on each Pascal line, three Pascal lines through each h-point; at each h-point two triangles in perspective, their vertices h-points, their sides Pascal lines; the axis of perspective being for each point the Pascal of the hexagon *unique to the center of the perspective.* It is a group of ten Pascal lines and their ten unique h-points.

(40) *Geometric relation between an h-point and its unique hexagon.*

None of the hexagons, 2, 3, 4, in h_1 in 38 enter into the h-points on the Pascal of abcdef (1), unique to (2, 3, 4). Thus h_1 is the center of perspective and the Pascal of (1) the axis of perspective for the two h-point triangles whose corresponding sides are 5, 6; 7, 8; 9, 10.

In the accompanying figure, the unique h-points and Pascals are numbered as II, 2; IV, 4; etc., giving ten centers of perspective, ten axes of perspective; for each center a pair of triangles in perspective.

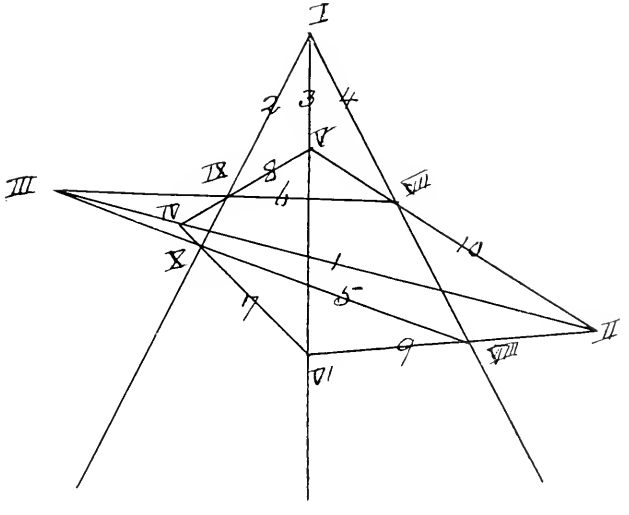

Fig. 1. A Veronese group as in 38 and 40. Ten such groups.

(41) *To write the six Veronese groups.*

Select the six hexagons of two conjugate g-points and treat each as was (1) in (38).

(42) A Veronese group may also be sorted out thus:

Start with any hexagon a b c d e f (1). Hold a, c fixed, permute all the other letters cyclically (forward); then hold c, e fixed; then e, a, giving:

a b c d e f (1)
a f c b d e (2)
a e c f b d (3)
a d c e f b (4)
c b e d f a (5)
c a e b d f (6)
c f e a b d (7)
e d a f b c (8)
e c a d f b (9)
e b a c d f (10)

(43) The six Veronese groups may be formed as in (42), by starting with the six lines of two conjugate g-points.

(44) No two h-points of a Veronese group and no g-point and h-point of such a group are connected by a G-line. These lines tie the different groups, one h-point from each of three groups, and a g-point from a fourth.

(45) *The ten g-points in any Veronese group lie on five I-lines, four points on each line, two lines through each h-point. (The arrangement of the ordinary five point star, four point star, or three point star).*

Write a b c d e f forwards and backwards as in

ab, cd, ef (F)
af, ed, cb (B)

Form from (F) and (B) two groups as follows:

$$\left.\begin{matrix} \text{ab, cd, ef (F)} \\ \text{ab, ef, dc (2)} \\ \text{ab, dc, fe (3)} \\ \text{ab, fe, cd (4)} \end{matrix}\right\} (A_1) \; ; \; \left.\begin{matrix} \text{af, ed, cb (B)} \\ \text{af, cb, de (5)} \\ \text{af, de, bc (6)} \\ \text{af, bc, ed (7)} \end{matrix}\right\} (A_2)$$

Here are seven hexagons in the Veronese group of (42).

On writing out the g-points *on* the Pascals of (A_1), they will be g_1, g_5, g_6, g_7 of 34; those on the Pascals of (A_2) are g_1, g_{10} g_9, g_8.

Thus any hexagon treated as in (A_1), (A_2) will give two lines of four g-points each, *inside the same Veronese group.* (The third line of g-points runs to different groups).

Now reverse (2), (3), (4) and form similar groups to (A_1).

$$\left\{\begin{matrix}\text{ac, df, eb(2)}\\ \text{ac, eb, fd(8)}\\ \text{ac, fd, eb(9)}\\ \text{ac, eb, df(6)}\end{matrix}\right\}(C);\quad \left\{\begin{matrix}\text{ae, fc, db (3)}\\ \text{ae, db, cf (5)}\\ \text{ae, cf, bd(10)}\\ \text{ae, bd, fc (9)}\end{matrix}\right\}(D);\quad \left\{\begin{matrix}\text{ad, ce, fb (4)}\\ \text{ad, fb, ec (8)}\\ \text{ad, ec, bf (7)}\\ \text{ad, bf, ce(10)}\end{matrix}\right\}(E).$$

Here is a total of ten hexagons, all in the Veronese group of (42).

Each set, A_1, A_2, C, D, E indicates a line of four g-points; and each hexagon occurs twice. Therefore the g-points within any Veronese group are on five lines, four points on each line and two lines through each point.

(46) *The star of g-points in each Veronese group.*

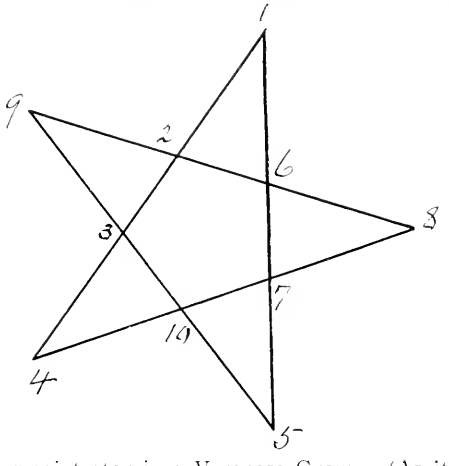

Fig. 2. The g-point star in a Veronese Group. (As it might be).

As shown by A_1, A_2, C, D, E; 2 in Fig. 2 indicates the g-point on the Pascal of hexagon (2).

A different arrangement of the points will give a three point or four point star.

(47) *Each pair of Veronese groups has an I-line of g-points in common.*

Any two hexagons related as (see 8),

ab, cd, ef (1)
ab, ef, cd (2)

give, when used as the leading lines of a set like (A_1) in (45), the same I-line; (2) will lead to the line g_1, g_7, g_6, g_5 on the Pascals of (A_1) in (45).

$$\left.\begin{matrix}\text{ab, ef, cd}\\ \text{ab, cd, fe}\\ \text{ab, fe, dc}\\ \text{ab, dc, ef}\end{matrix}\right\} \begin{matrix}(2)\\ \\ (F).\\ \\ \end{matrix}$$

But (A_1) and (F) belong to different Veronese groups.

Thus the six stars of the I-lines in the six Veronese groups are linked by having one line in common between each pair; each star has one line in common with each of the five other stars. See (48), which shows that all the stars could not be five pointed.

(48) *Numerical table for the I-lines of g-points.*

Selecting any g-point as

$$\left.\begin{matrix}\text{ab, cd, ef}\\ \text{ed, af, cb}\\ \text{cf, eb, ad}\end{matrix}\right\} \ (1)$$

the collinear groups of I-lines through (1) have for initial lines of their g-points:

$$\left.\begin{matrix}\text{ab, cd, ef (1)}\\ \text{ab, ef, dc (2)}\\ \text{ab, dc, fe (3)}\\ \text{ab, fe, cd (4)}\end{matrix}\right\} \ ; \quad \left.\begin{matrix}\text{ed, af, cb (1)}\\ \text{ed, ch, fa (5)}\\ \text{ed, fa, bc (6)}\\ \text{ed, bc, af (7)}\end{matrix}\right\} \ ; \quad \left.\begin{matrix}\text{cf, eb, ad (1)}\\ \text{cf, ad, be (8)}\\ \text{cf, be, da (9)}\\ \text{cf, da, eb (10)}\end{matrix}\right\}$$

Denote by 2 the g-point on the Pascal of hexagon (2), etc. and write the above lines thus:

	1	
2	5	8
3	6	9
4	7	10

(a) The vertical columns are I-lines through 1.

(b) The line joining 2 and 5 meets that joining 3 and 6 at 10′ (the conjugate of 10); and so, in general, the line joining any two points in a horizontal line meets the line joining any other two, in another horizontal line and in the columns of the first two, in the conjugate of the point not in these columns nor lines (2, 8 meets 4, 10 at 6′; 7, 10 meets 6, 9 at 2′, and so on).

(c) Any two points in a horizontal line are in a line with the conjugates of those not in the line nor columns of this selection (2, 5, 9′ 10′ is a line; 3, 9, 5′, 7′ is a line, etc.)

d The conjugates of the horizontal lines are in line with 1′ (1′, 2′, 5′, 8′ is a line, etc.)

Proof of (c) and (b):

Collinear groups with (2) (in addition to that given) are (using other hexagons in a g-point with (2)):

$$\left\{\begin{matrix}\text{ac, eb, df (2)}\\ \text{ac, df, be (5)}\\ \text{ac,be,fd (10′)}\\ \text{ac, fd, eb(9′)}\end{matrix}\right\}\ \text{(L)}\ ;\quad \left\{\begin{matrix}\text{af, ec, db (2)}\\ \text{af, db, ce (6′)}\\ \text{af, ce, bd (8)}\\ \text{af, bd, ec (7′)}\end{matrix}\right\}\ \text{(M)}$$

as tested by sections 4 and 5.

And collinear groups with (3) are:

$$\left\{\begin{matrix}\text{fc, ae, db (3)}\\ \text{fc, db, ea (8′)}\\ \text{fc, ea, bd (6)}\\ \text{fc,bd,ae (10′)}\end{matrix}\right\}\ \text{(N)}\ ;\quad \left\{\begin{matrix}\text{de, fb, ac (3)}\\ \text{de, ac, bf (5′)}\\ \text{de, bf, ca (9)}\\ \text{de, ca, fb (7′)}\end{matrix}\right\}\ \text{(O)}$$

(L), (M), (N), (O) prove (C), while (L) and (M) show that line 2, 5 meets line 3, 6 at 10′, and so in same way for other statements.

Taking the g-point conjugate to 1, and treating it the same way as 1, we get

1′		
6′	5′	7′
3′	2′	4′
9′	8′	10

as is easily tested.

Thus the fifteen I-lines given by the numerical table are:

1, 2, 3, 4	6, 9, 2′, 4′
1, 5, 6, 7	4, 7, 8′, 9′
1, 8, 9, 10	4, 10, 5′, 6′
2, 5, 9′, 10′	7, 10, 2′, 3′
2, 8, 6′, 7′	1′, 2′, 5′, 8′
5, 8, 3′, 4′	1′, 3′, 6′, 9′
3, 6, 8′, 10′	1′, 4′, 7′, 10′
3, 9, 5′, 7′	

as illustrated on the following diagram.

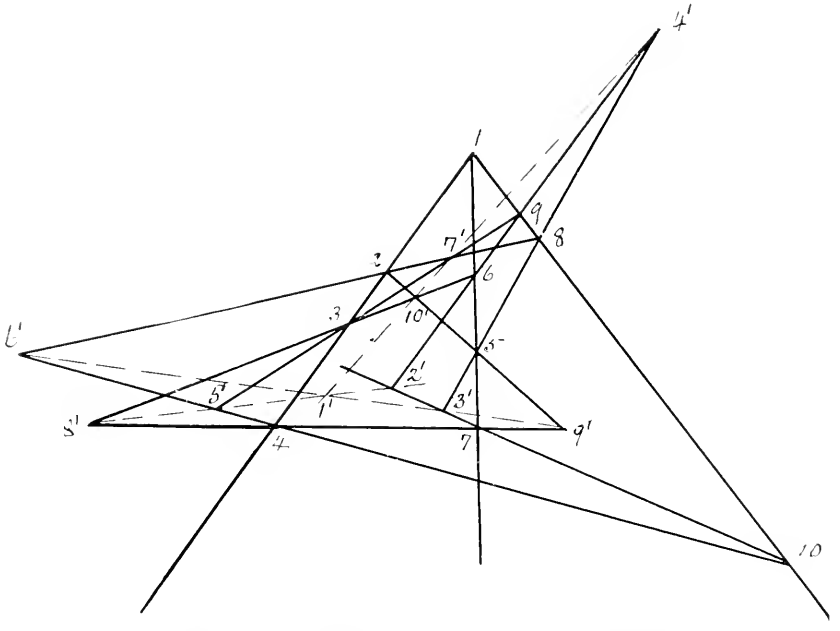

Fig. 3. The 15 I lines and 20 g points. 10 g points and conjugates.

(49) *The g-points not connected by I-lines.*

In the Veronese group in (46), no line runs from the g-point 1 on a b c d e f (1) to 8, 9, 10, but this

$$\left.\begin{matrix}\text{ace, bfd} & (8)\\ \text{cea, dbf} & (10)\\ \text{eac, fdb} & (9)\end{matrix}\right\} \text{(h)}$$

is the point unique to (1) (See section 9).

Thus in any Veronese group, no g-point on the Pascal of any hexagon is connected by I-lines to the g-points on the Pascals of the hexagons of the h-point unique to the given hexagon.

Through each point pass three Pascal lines (of different Veronese groups), and thus the g-point 1, is not connected to any of the g-points on any of the Pascal lines of any of the nine hexagons unique to the hexagons of the given g-point; and no g-point is connected by an I-line to its conjugate g-point.

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OUTLIERS OF THE MAXVILLE LIMESTONE IN OHIO NORTH OF THE LICKING RIVER.*

By G. F. Lamb.

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It is well known to those familiar with Ohio geology that the Maxville limestone is the uppermost formation of the Mississippian system found in the Ohio scale, that its outcrop is limited in extent, patchy in character, and that the overlying Pennsylvanian beds rest upon it unconformably.

William C. Morse, in Bulletin 13 of the Ohio Geological Survey, published in 1910, presents the most complete account of this formation published. It is shown in this bulletin that up to 1910 all the known outcrops of this formation occur south of the Licking River, extending from a point a little southwest of Zanesville, on the north, to the vicinity of Portsmouth on the Ohio River. It is further shown that the most important area of outcrop lies at the north and extends from near Zanesville southward to the vicinity of Logan—an area about 25 miles long and 10 or 12 miles wide.

It has long been supposed that this formation once extended to the northern part of the state and was removed by post-Maxville pre-Pennsylvanian erosion. The supposition was based upon the presence of lime cobblestones more or less silicified found at the bottom of the Coal Measure basal conglomerate, and which were said to carry Mississippian fossils. Since no other Mississippian limestone was known to occur in the state, it was concluded the cobbles must have been derived from the Maxville.

It is the purpose of this paper, (1) to point out the northward extension of this limestone, (2) to throw further light on the origin of the cobble stones, and (3) to emphasize a reason for its absence in the northern part of the state.

The writer has found various outcrops of this limestone as far as 40 miles north of Zanesville in a belt 10 to 12 miles wide extending northward across Muskingum, Coshocton and into southern Holmes County. They invariably occur in isolated

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places, and not more than three of the outcrops could be other than outliers.

A few of these outcrops may be described briefly. About 7 miles northwest of Zanesville on the north side of the Licking River and about 11 miles north of the Fultonham outcrops described by Morse, two outcrops were found well exposed in ravines about $\frac{3}{4}$ mile apart. The limestone is bluish gray, fine grained, compact, without prominent bedding planes and 3 to 7 feet in thickness. No fossils were found, and it appears to be the lower division of the Maxville described by Morse. Apparently it rests conformably upon the Logan shale, but is overlain unconformably by Coal Measure sandstone.

It was again found in bed north of the Walhonding River, $2\frac{1}{2}$ miles north of Walhonding Village and 2 miles south of the village of Tiverton Center in northwestern Coshocton County. There six feet of the limestone is well exposed in a deep ravine, contains considerable iron, weathers to the color of yellow clay—indeed almost to the yellow of ochre. The top and bottom weather to a brown. It looks so very like a compact yellow clay that one's first impression of it is that it really is a bed of clay. Digging into the yellow mass 4 to 6 inches dispels the illusion by finding the familiar fine grained light gray limestone. The upper surface as seen in the ravine side is uneven and is overlain by 2 feet of light green mud mingled with flinty cobbles of limestone. The mud bed appears to be the residual material of the decomposing limestone.

Resting directly upon the mud bed is the pebbly Coal Measure rock. This peculiar green mud carrying angular cobble stones, and the underlying limestone weathering to an ochre color is very like exposures found by Morse far to the southward.

Eight miles southeast of the above exposure is the town of Warsaw. Several outcrops occur at 1 to 4 miles north and east of this place which range from 2 to 9 feet in thickness. Two miles east of Warsaw an outcrop presents the ochre weathering phase in marked degree. Four miles east of Warsaw and 6 miles northwest of Coshocton in the high bluff overlooking the junction of Killbuck Creek and Walhonding River occurs the most easterly outcrop found. Three feet of hard gray limestone in several layers weathering brown are exposed and with neither top nor bottom seen.

Probably one of the most instructive outliers found occurs 4 miles north of Warsaw and 1 mile south-west of Blissfield on the Blissfield-Warsaw highway. The exposure occurs in the highway at the crest of the ridge and shows 9 feet of the limestone in many layers resting conformably upon the Logan shale a long section of which is exposed. Resting directly upon the limestone is a bed of sandstone 12 to 18 inches thick, sharply undulating, and strikingly unconformable. The sandstone is white to gray in color, very compact, and exceedingly hard. The limestone is well weathered, is soft, buff to yellow in color, and contains many fossils of brachipods and fenestellid bryozoans. When completely weathered, as seen in the roadway nearby, it becomes an ocherous earth.

One of the most interesting facts is the presence of hard concretionary nodules more or less silicified and definitely embedded in the limestone. They are precisely like the thousands of loose cobble stones seen in dozens of places where no bed of limestone was found. The writer had believed for some time that where beds of these loose cobbles were found, or where they were numerous, they marked the place of the Maxville limestone, but up to the finding of this outcrop he had no positive evidence of their origin.

It may be pointed out that this outcrop marks the crest of a Mississippian hill, as these patches usually do. North, east, and south the Mississippian surface falls a hundred feet or more. In a hill close by, the Lower Mercer limestone is found only 50 feet above the Maxville—an interval that is usually 120 to 150 feet between the Lower Mercer limestone and the base of the Pennsylvanian.

Noting the elevation at which the various outcrops occur, it is found they all lie in one plane very gently dipping to the south-east. It may be stated further that the many beds of cobble stones found at the Mississippian-Pennsylvanian contact all lie in this same plane. This indicates in no uncertain way that the cobble beds are the remains of the Maxville and mark its place.

The most westerly point at which a bed of cobbles was found is in Licking County, 8 miles north-east of Newark and 4 miles north-west of Hanover. The exposure is in the roadway on the western edge of Perry Township. The stones range in size from the fist up to 15 or 18 inches in diameter, are

generally flinty in character, weather white, and are fossiliferous. This description will apply to all the cobble beds except in point of size.

The most northerly beds found occur about 5 miles south of Glenmont in Holmes County, where the surface in places is strewn with cobbles. At one point on top of a ridge, besides the cobbles the soil is all a rich chocolate color. The area is an acre or two in extent and is the residue of the fully weathered limestone.

It is now known that the Maxville is found two-thirds of the distance across the state with strong probability of still further extent formerly.

Taking the Berea sandstone as a datum plane in the general direction of the Maxville outcrop, it is found that the Berea-Maxville interval increases northward. In Vinton County the interval between the top of the Berea and the top of the Maxville is about 650 feet; at Rushville, in eastern Fairfield County, about 800 feet; at New Castle, in Coshocton County, 840 feet; near Killbuck in southern Holmes County, 870 feet; and 20 miles north of the last point in central Wayne County east of Wooster, 900 feet of shale and sandstone above the Berea does not quite reach the Maxville horizon. Northward from Wayne County the total thickness of the Mississippian strata decreases notably, due to greater erosion in late Mississippian time. In north-eastern Ohio the Pennsylvanian beds lie, commonly, only about 3 to 4 hundred feet above the Berea, and in the old Mississippian river valleys, clearly defined in this area, the Sharon Conglomerate sometimes lies but 100 feet above the Berea.

If the plane of the Maxville be projected northward to Cleveland with the slowly increasing interval between it and the Berea, the Maxville would lie about 1050 feet above the Berea.

In the light of these facts it is apparent that the Maxville can not be found in northern Ohio, and that outcrops may not be expected beyond northern Holmes, or central Wayne County.

It will be noted further that these figures reveal the interesting fact that the Mississippian System thickens northward, although thinest in the northern part of the state now, as a result of greater erosion.

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OCCURRENCE OF CARBONACEOUS MATERIAL IN THE GREENFIELD MEMBER OF THE MONROE FORMATION.

CHARLES W. NAPPER.

At the Rucker quarries in Greenfield in southwestern Ohio, is the largest and most important exposure of this member in the Monroe formation. Above the water level of Paint Creek there are 45 feet of stone, and quarrying has been conducted as deep as 15 feet below this level. The entire vertical extent, which is of the Greenfield member, is 60 feet. The rock is a dolomitic limestone and is divided into two parts, the lower strata gray and the upper ones buff. The gray is a hard, solid limestone, while the buff, although firm, breaks more easily under the hammer. In addition to the color the occurrence of carbonaceous material also serves to differentiate the two parts. The Greenfield stone is of a very close texture and with the exception of occasional masses having crevices, its firmness, solidity and density are distinguishing characteristics. The stone is rich in carbonaceous material which is disseminated throughout its entire extent, as it has little opportunity to collect in any large quantity. When the stone is freshly broken this material gives it a bituminous odor which is a helpful test in distinguishing this rock from other formations.

The Gray Stone.—In the gray stone carbonaceous material is evidenced in three ways in addition to the odor test.

First.—In a thin ledge within a foot of its lowest worked level this carbonaceous material is volatile. As pieces are broken off it evaporates much the same as gasoline when poured out.

Second.—Throughout the gray stone carbonaceous material manifests itself by the profusion of carbon lines. They are as numerous as twenty or twenty-five to the inch. Their size is similar to that of lines drawn with a fine pen point. They do not occur at regular intervals; one inch will be full of them, then a clear space of a fractional part of an inch, then more lines. When they occur close together at intervals, they give the rock the appearance of having a banded structure. Usually they are parallel, and not often wavy unless bending around a quartz-lined cavity or a nodule of sphalerite. The

rock can be split along these lines and the surfaces will show hard, dry, carbonaceous material either solid in extent or in patches. In the gray stone these lines are all through it, while in the buff stone the few that occur are usually found near the edges of the ledges.

Third.—Carbonaceous material also occurs in the gray stone in sheets. These sheets occur at the parting line between the ledges, especially between the strata near the contact between the buff and the gray stone. Particularly after blasting these sheets can be taken out entire as large as two feet square. The average thickness is almost 1/32 inch, and they are sometimes as thick as 1/16 inch. When these sheets are placed in the fire they burn with an oily, sooty flame, leaving a thin rock stratum. The sheets are not consumed as a shingle would be, but the carbonaceous material seems to burn out as if the sheet were soaked in oil. This suggests that these sheets are very thin limestone layers heavily impregnated with carbonaceous material.

When these carbon dividing planes of the lower layers are split they often show the obverse and reverse of the fossil plant, **Sphaerococcites** (?) **glomeratus** Grabau. It is a ready inference that these sheets and lines mark the beds of this plant, from the decay of which they received their carbon material. The objection that the lines are often noticed in the buff stone where this fossil plant is not found can be met by the statement that as the lines are thickest and most profuse in the gray stone there would be the most natural place for the distinctive preservation of the fossil. Further, the harder texture of the gray stone which prevents the carbonaceous material from penetrating the rock would also serve to preserve the fossil plant distinctively and in its entirety. It also suggests that the gray stone was built up by successive flourishing of the plant and deposition of rock material. As the gray stone is hard and very solid, we do not find carbonaceous material other than as just stated, as it has no opportunity to seep through the rock and collect in masses of "rock tar."

The Buff Stone.—The buff stone being softer, less dense and with numerous cavities, its carbonaceous material has the opportunity to present itself more distinctly than in the gray stone. While carbon lines do occur, yet they are never in profusion

and are to be found in only a few strata other than have been mentioned. The buff stone is most carbonaceous where it is nearest the gray. The odor test indicates that the buff stone is equal to the gray in its carbon element. It also manifests itself in three additional ways.

First.—In breaking the buff stone we frequently find that its looser texture has permitted the carbonaceous material to gather between the rock particles. The stone appears as though stained with some heavy black oil or fluid.

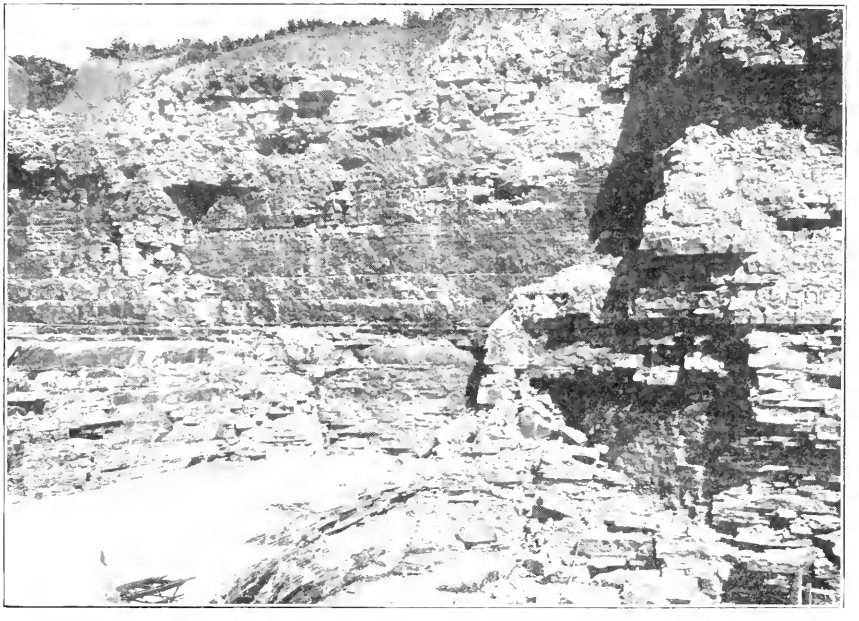

FIG. 1. The Greenfield member of the Monroe formation, Rucker quarries, Greenfield, Ohio.

1. Drift.
2. Buff stone, with heavy layers and carbon sheet zone toward the base.
3. Gray stone, with carbon lines.

Second.—Carbon sheets are more frequent and better defined in the buff than in the gray stone. They occur between the lower ledges; in fact, from two feet below to six or eight feet above the contact of the gray and buff stones is the carbon sheet zone. There seems to be a gradation from the profuse carbon lines of the gray stone to their total absence in nearly all of the buff. The dominant distinguishing feature of the

buff stone in this particular exposure is the almost complete absence of carbon lines, which causes it to stand out in strong contrast to the gray stone with its profusion of these lines.

Third.—Throughout the buff stone of this particular exposure, but especially numerous in its heavier lower ledges, occur "cup and cone concretions." These peculiar forms are fully treated in another paper, but for the present study the cavity usually present with them affords the best place for the collection of carbonaceous material. These "concretions" do not occur in the gray stone, and it seems that the looser texture of the buff stone favors their formation.

From the rock surrounding the cavities the carbonaceous material drains into them. Here the natural "rock tar" is found. Sometimes it spreads out and fills the cavity; sometimes it adheres to the walls of the cavity in drops as large as the end of the little finger. This is pure, solid carbon material, hardened and brittle; when heated it becomes waxy and burns with a heavy, oily flame. While a rare form, Figure No. 3 admirably illustrates how this collection does take place. The drop in the cavity at the termination of a carbon line along which has been the flow is conclusive evidence. Also on the sides of the "cup and cone concretions" are lines of fracture where carbonaceous material accumulates. Here it appears in streaks.

Summary.—The Greenfield member of the Monroe formation contains much carbonaceous material, evidenced by odor, carbon sheets and lines, carbon stains, and solidified "rock tar." Its close texture prevents that accumulation necessary for a paying gas or oil rock. If its texture were open and spongy then it might have had economic value other than that for building and agricultural purposes.

EXPLANATION OF PLATE.

FIG. 1. Occurrence of carbonaceous material in gray stone. "Carbon sheets" occur between layers nearest contact with buff stone in which they are far more numerous. "Carbon lines" are profuse throughout the gray stone and serve to distinguish it.

FIG. 2. Occurrence of carbonaceous material in buff stone. Upper layer stained with carbon material; lower layer to show collection in cavities and in "cup and cone" concretions.

FIG. 3. "Rock tar" in buff stone. Collection and flow have been along carbon line, terminating in carbon drop in cavity.

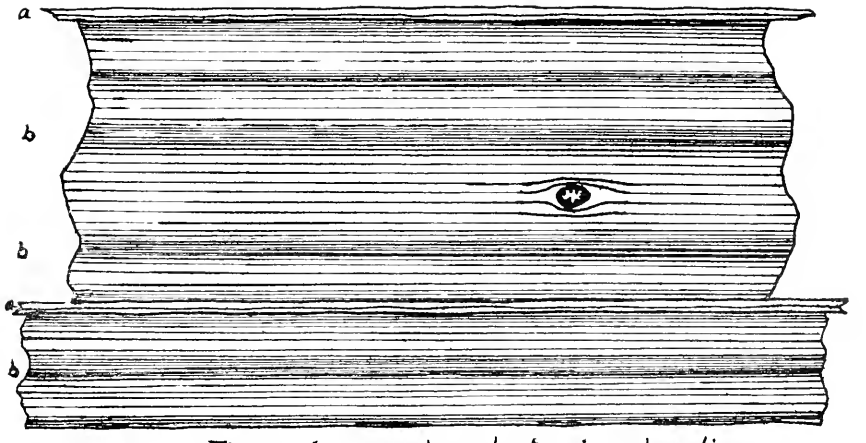

Figure 1. a, carbon sheets; b, carbon lines.

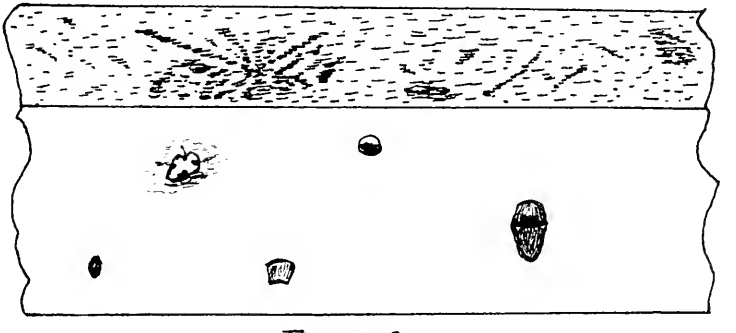

Figure 2.

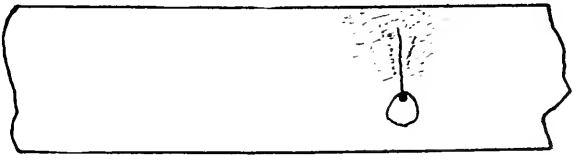

Figure 3.

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HOMOPTEROUS STUDIES. PART I.

Contribution Towards Our Knowledge of the Homoptera of South Africa.

ERIC S. COGAN, M. A.

INTRODUCTION.

The systematic treatment of the Auchenorrhynchous Homoptera of South Africa has received but little attention from entomologists and naturalists, with the result that the worker or investigator finds himself confronted with what may be termed a pioneer task. Of all the orders of insects in South Africa, the Hemiptera and particularly the suborder Homoptera have been studied the least. The list of described species, at all events for the Auchenorrhynchous Homoptera, would scarcely number more than one hundred. The Cicadidæ and Fulgoridæ are perhaps the best known, yet our knowledge of these two large families is far from complete. The Membracidæ have received but passing comment, while the Cercopidæ and Jassoidea are scarcely known at all.

Through the courtesy of Professor Osborn of the Ohio State University, the writer was afforded an opportunity to study a series of Cercopids and Jassids, which had been consigned to him for study by Mr. Mally, of the Department of Agriculture in the Cape Province. Except in a few cases where the specimens had faded a little, the collection was in a good state of

preservation. In all some thirty-eight forms were studied and the results are embodied in the following pages.

It will be seen that the generic descriptions have been given; and this is done in view of the fact that the writer here wishes to lay the foundation for future extensive study of the families concerned. In some cases species have been redescribed fully, because the original descriptions are brief, totally inadequate, and not readily accessible to the average worker. Where species are described as new the writer has endeavored to present, as far as possible, accurate drawings to supplement the descriptions. On account of the growing importance of the ecologic and economic relationships of Insects, a short discussion of these two phases of study is given.

The types of new species will be deposited in and numbered at the South African Museum, Cape Town.

ACKNOWLEDGMENT.

I desire here to express my sincere thanks to Professor Osborn, of the Department of Zoology and Entomology of the Ohio State University, for much valuable suggestion and criticism, and for facilities placed at my disposal; to Mr. Hewitt of the Albany Museum, for the loan of specimens and to my father, Mr. R. J. Cogan, for material forwarded to me for study.

HISTORICAL.

The earliest references to the Homoptera of South Africa are contained in Linne's work, Systema Natura, Ed. X, published in 1758, wherein the descriptions of four Cicadas and a Fulgorid are contained. During the same century, Fabricius was responsible for the descriptions of some few forms which had been collected by the early voyagers and explorers of the Cape of Good Hope. Among others De Geer may be mentioned as contributing to our knowledge during the same period. The first half of the nineteenth century was not productive of many workers in the suborder—Germar, Westwood, Guerin, Anyot and Serville, Thunberg and Burmeister, were perhaps the most prominent. But the year 1850 saw the appearance of Walker's List of Homopetra in The British Museum and during the succeeding two decades, considerable work was done by Stal, Signoret and Westwood.

Walker's List with Supplement was completed in 1858, and contained the descriptions of numbers of South African Genera and species. Concerning his work, Distant has written: "Walker was a prolific and somewhat hasty writer, and the value of his work was very uneven. His name is however associated with and never can be excluded from the annals of the South African Homoptera, or scarcely from those of any other region: he was a pioneer, though his survey required and still requires much supervision."

Stal's monumental work, Hemiptera Africana appeared in 1866, and is held today as the most comprehensive work ever accomplished on the order, so far as South Africa is concerned. Of him Distant writes: "Stal built on his own foundation, he possessed a genius for taxonomy; what Lacordaire did for Coleoptera, he more than achieved for the Rhynchota and his work may be further elaborated, but will never be superseded. He was a severe critic of Walker's work and even proposed its suppression." Stal wrote almost exclusively in Latin with a style all his own, and it has been the lot of many Hemipterologists to experience difficulty in translating many of his expressions. He apparently collected in South Africa, although the majority of his work was done on Museum material.

Associated with the names of Stal and Walker may be mentioned Signoret, the French collector and taxonomist. During the years 1853 to 1856, he published in the Annals of the Entomological Society of France, quite a number of descriptions of South African Homoptera, chiefly of the family Jassidæ. Later (1880), his "Essai sur les Jassides" appeared.

Of the more recent workers and investigators, the names of Distant (Rhynchota), Melichar (Homoptera), Karsch 1890, (Fulgoridæ), Buckton 1903, (Membracidæ), Schouteden 1901, (Cercopidæ), and Jacobi 1904, (Cercopidæ), stand out prominently. Distant is perhaps the highest living authority on the Homoptera of South Africa and has contributed many valuable works on the group. Chief among these may be mentioned his "Synonymic Catalogue of Homoptera," his "Insecta Transvaaliensia," and many papers in the Annals and Magazine of Natural History. Melichar's work has been restricted somewhat to the German East African province, where he has collected extensively and described numbers of forms.

With the rapid development of Agriculture in the South African provinces, more attention is being paid to the study of Entomology and since a knowledge of systematic work is indispensable to the economic worker, the study of the Hemipterous order is receiving more attention. The Homoptera will necessarily come in for their share of study and one may predict a healthy development in the near future of our knowledge of this group.

ECONOMIC.

The development of the study of Economic Entomology has brought to light the fact that many of the supposedly insignificant and inconspicuous forms of insects are in reality responsible for a great deal of damage to the crops of man. During recent times attention has been paid to the investigation of many Homopterous insects with the result that the Jassids have been found responsible for a great deal of injury to grains, grasses and cereals; besides native grasses, plants and trees. Although as yet none of the Auchenorrhynchous Homoptera in South Africa have been proven to be of great Economic Importance, it would be unsafe to say that such would always be the case. Distant in his Insects Transvaaliensia, points out that "as many of the species generally referred to as "Leafhoppers" by American Entomologists, are undoubtedly injurious to several trees and crops, a knowledge of them, however partial, is of economic importance." Osborn further states that "the leafhoppers affecting the cereal and forage crops constitute a very constant factor and the extent of the drain on such crops is doubtless much greater than is appreciated."

Entomological work in the United States and territories has revealed the depredations of many members of the Homopterous suborder: thus the Periodical Cicada (Cicadidæ), the Buffalo Tree-Hopper (Membracidæ), the Sugar Cane Leafhopper (Fulgoridæ) in Hawaii, and the many Froghoppers (Cercopidæ) and Jassids (Jassoidea), may be cited as examples of the general importance of the group from an economic standpoint. Records of extensive injury to crops by members of the superfamily Jassoidea are obtainable in the United States—thus Deltocephalus inimicus, Athysanus exitiosus, Dræculacephala mollipes and D. reticulata, Agallia sanguinolenta, and Cicadula 6-notata, constitute in some parts a great

enemy to the cultivation of cereal and forage crops. Empoasca mali on Apple and Typhlocyba comes on Grape may also be mentioned to show the effect on plants other than grasses and cereals.

The Jassoidea and Cercopidæ are not restricted to grasses, but are equally formidable in their attacks on fruit trees, garden crops and shade or forest trees. Although their attacks are not as prominent or apparent as those of the Locusts or Scale Insects in South Africa, yet by their inestimable numbers they are considered to account for much of the trouble, which is usually ascribed to other causes.

Their method of attack is restricted almost entirely to the sucking of the plant juices and sap, thus causing a general wilting of the parts affected. The leaves and younger stems are especially affected and the result is generally seen in the small brown spots, indicating the punctures of the insect's "beak." Where immense numbers of these minute insects attack a crop, it can easily be seen that the incessant and constant drainage of the sap will result in some material loss.

As pointed out before, none of the South African leafhoppers have yet proven to be of great economic importance, but the general distribution and common occurence in meadows and pastures of Athysanus capicola makes it a very suspicious species. Added to this, the six-spotted leafhopper, Cicadula 6-notata is now reported from the Cape Region and when one considers its work in North America and Europe, it would not be unfair to expect a similar state of affairs in South Africa.

The practice of burning the grass or veldt, is one which though not very strongly recommended by the botanists, nevertheless, serves to keep down the grassfeeding species of Jassids. Owing to the nature of farming in South Africa, the control conditions must necessarily be of a restricted variety, and local more than general methods recommended.

ECOLOGIC.

Osborn states that "the leafhoppers constitute one element in a very complex relation of plants and animals, including birds, mammals, reptiles, toads, insects and spiders, etc., and it is only by the recognition of this relation that we can offer any adequate explanation of their proper place in nature, and of their importance in the economy of cultivation. Primarily

they are associated with certain kinds of plants upon which they depend for their sustenance and the abundance of leafhoppers will be affected, necessarily, by the abundance of the food plant and its availability as food material. An undue increase of the leafhoppers, which should result in the diminution of the food supply, must necessarily affect the possibilities of multiplication and cause a certain reduction in the number of the insects. This is by no means the only statement of conditions, as, aside from these two forms which may be associated in the same area, a large number of other organisms, both plant and animal, will affect the problem. The occurrence of different birds and predaceous insects which prey upon the leafhoppers will naturally reduce their numbers and to that extent favor the plants which serve as their food, whereas the presence of herbivorous animals, grasshoppers, cutworms, etc., serves to reduce the available food supply. Aside from these dominant forms, there are also various fungus parasites which attack both insects and plants and which play their part in the complex, of which the leafhoppers are such a conspicuous element. Furthermore, the minute insect parasites which attack the leafhoppers add their part, tending to keep the latter reduced in numbers."

Some of the points here mentioned are well borne out in South Africa; thus the increase in vegetation from the west to the east, is followed by a great increase in the numbers of forms, with the result that the Eastern Province and Transkei territories (the Caffraria of Stal), contain a greater number of individuals. It must be emphasized here that but mere passing comment on the ecological relations can be given, as our knowledge of the group precludes any but bare statements of recorded observations. The presence in South Africa of a fauna restricted almost entirely to the dry Karroo region, makes the study of ecology an interesting one. Added to this the subtropical character of the climate and vegetation of Natal, and the northern regions, one is confronted with a variety of conditions scarcely paralleled on any other continent. Many of the endemic genera and species are restricted almost entirely to the Karroo region.

The relations of the higher animals to the Homopterus fauna can only be touched on. While it is known that herbivorous animals in foraging, are likely to swallow the eggs, yet the

matter is of minor importance. As with the locusts, the birds must necessarily constitute some check on the increase of the fauna. The writer recalls the swallows feeding extensively on Jassids in the district of Albany. Another interesting fact is recalled, and that is the habit of the common "Butcher Bird," which catches and impales various insects, such as Grasshoppers, Cicadas, Fulgorids and Jassids, on barbed wire fences and on thorns of trees such as the "Mimosa." Distant records that "birds are dangerous to Cicadan life," and further reports having seen a Cicada, *Platypleura diversa* Germ. eaten by spiders. Ross records the eating of *Quintilia carinata* Stal by a mantis (*Miomantis fenestra* Fab.). Near Rustenberg he observed *Callipsaltria longula* Stal being attacked by a Cicindelid beetle. Bell-Marley writes of an interesting interrelationship existing between a Membracid *Oxyrhachis tarandus* Fabr. and certain small red ants; the cause of the association being the secretion of honey dew by the Membracids.

The protective resemblances borne to plants and flowers by many African Homoptera, constitute an interesting association and are worthy of mention here. *Cephalelus infumatus* is perhaps the best and most striking example, and the case of mimicry is mentioned under that insect later. Distant records a resemblance to twigs and branches by a Cicada, *Platypleura haglundi* Stal, and Ross attributed the difficulty in collecting *Platypleura marshalli* Dis. to its resemblance in color to the "mopami" tree. Hinde has drawn attention to the resemblances borne by *Flata nigrocincta* Walk. to flowers of a plant in East Africa.

While many interesting ecological facts await the investigator, it seems to the writer that none too much stress can be laid on the importance of such study. The various predaceous and parasitic insects must necessarily be studied before we can obtain any definite information on the ecological relationships.

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FAMILY CERCOPIDÆ.

This interesting family is characterized by the shape of the hind tibiæ, which are cylindrical and armed with two spines on the outer side, one near the base, and the other a little beyond the middle, the former once and the latter twice as long as the tibiæ are wide. Tibiæ and first two joints of the tarsi terminated with a crescent-shaped row of spines, and the third joint with a bifid claw. Frons usually tumid and convex or compresso-produced. Antennæ inserted between the eyes. Two ocelli located on the disc of vertex. Pronotum sixangular or trapeziodal; scutellum triangular or rhomboidal. Elytra coriaceous, more or less covered with a fine pubescence.

The family comprises the well-known "Cuckoo-spit," "Frog-hoppers," or "Spittle Insects," so called from the frothy enveloping exudate in which the early history of the insect is spent. The chief works on this family are those of Walker, Stal, Distant, Schouteden and Jacobi.

TABLE OF SUBFAMILIES OF CERCOPIDAE.*

1. Anterior margin of the thorax straight, eyes equally as long as broad..... *Cercopida Stal.*
2. Anterior margin of the thorax rounded or angular: eyes frequently transverse. *Aphrophorida. Stal.*

SUBF. CERCOPIDA Stal.

SYNOPSIS OF GENERA.*

A. Front without a longitudinal carina.
   a. Front with a longitudinal sulcus.....**Rhinaulax. A. & S.**

AA. Front with one or more than one longitudinal carina at middle. Front with one carina.
   b. Carina weak, not well developed.....**Locris. A. & S.**

Genus **Rhinaulax** A. & S.

Head broad, the front convex and broadly flattened or impressed from the middle of the base to beyond the middle of the length. Ocelli remote from the eyes. Antennæ three-articulate, extending out almost from the sides of the head. Thorax truncate before the base of the scutellum. Scutellum equilateral.

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*Adapted from Stal.

Rhinaulax analis Fabr.

Cercopis analis, Fabricius. Ent. Syst. IV. 49. 7. (1794).
id. Syst. Rhyng. 93. 23. (1803).
Cercopis bicolor, Fabr. Ent. Syst. Suppl. 523. 11. (1798).
id. Syst. Rhyng. 93. 26. (1803).
Cercopis trifurca, Thunb. Hem. Rostr. Cap. 1. 4. (1822).
Tettigonia bicolor, Thunb. Hem. Rostr. Cap. 1. 7. (1822).
Rhinaulax maculipennis, Am. & Serv. Hist. Hem. 561. (1843).
Rhinaulax analis Stal. Hem. Afr. IV. 65. (1866).
Rhinaulax analis Distant. Ins. Transv. IX. 227. (1908).
Rhinaulax analis Walk. List. Hom. B. Mus. Suppl. 667. (1851).

General color black, with the elytra red, or varied. Length of female and male, 8 mm. Breadth 3 mm.

Vertex black, short, the anterior margin rounded, three times as broad as its length. Ocelli black, located closer to one another than to the eyes. Eyes oval, grayish black in color. Face black, the frons tumid, flattened on the middle, with numerous transverse furrows; clypeus produced, flat; rostrum long, black. Pronotum black, finely punctate, with indistinct rugæ, much broader than the head; a median longitudinal line; length about two and a half times as long as the vertex; convex above. Scutellum long, the apex sharp, depressed on the middle, with indistinct transverse striations; not quite as long as the pronotum. Sternum of thorax black. Elytra red at base, yellowish towards the apex black along the inner margin. Abdomen black above, beneath black, with the posterior edges of the segments red; red at base. Genitalia of male rather obscure; last ventral segment about twice as long as the penultimate; plates long, rounded.

Habitat: Caffraria (Castelnau), Cape Colony (Distant), Post Elizabeth, Simonstown (Oxford Museum), Rosebank C. P. (Brain).

Rhinaulax analis var. **bicolor.**

Black, with the elytra yellowish green, with black along the inner margin and brownish on the apical area. Abdomen black, with yellowish at base. Last ventral segment of female reddish; pygofers long and flattened, the ovipositor a little longer.

Habitat: Newlands, C. P. (Brain) and as above.

This species is most variable, Stal having described no less than three different varieties. The variety 'bicolor' seems to have a very general distribution over Cape Province, but is as yet not recorded from the neighboring provinces.

Genus **Locris** Stal.

Frons very tumid, convex, prominent in front and below; viewed from the side, neither compressed nor angular in form unless very obsolete; provided with a distinct carina on the

middle. Antennæ very short, ocelli further removed from the eyes than from one another. Base of thorax truncate. Scutellum subequilateral.

"According to our present knowledge, this is distinctly Ethiopian Genus. It is also a most extensive one, some forty two species having already been described. As pointed out by Stal, two subdivisions of the genus are possible by the character of the surface of the pronotum." (Distant).

A. Pronotum very coarsely punctate and posteriorly rugose.
B. Pronotum distinctly punctate but not posteriorly rugose.

A. Locris arithmetica Stal.

Locris arithmetica Stal Hem. Afr. IV. 58. (1866).
Monecphora arithmetica Walk. List. Hom. B. Mus. 675. (1851).
Locris arithmetica, Dist. Ins. Transv. IX. 227. (1908).

General color bright red, interspersed with black marks on the head, thorax and elytra. Ventral color black, the whole covered with a dense pubescence. Length of both male and female 12.5 mm. Breadth 4.5 mm.

Head small, much narrower than the pronotum; vertex produced anteriorly, its length about equal to the width across the eyes; anterior half of vertex red, the posterior, dense black. Eyes large, dark gray. Frons black, red at the anterior margin of the head, very tumid; longitudinal carina rather poorly developed; numerous deep transverse furrows; cheeks very small and rostrum long. Pronotum a little more than one and a half times as long as the vertex, narrow next the head, widening considerably towards the elytra; black on the anterior half, except along the lateral margins which are red; the red band continuous across the middle. Posterior margin black; pronotum very convex, finely punctate, the punctations occupying fine rugæ on the posterior half; anterior half with numerous small depressions or irregular pits; lateral posterior angles of the pronotum obtuse, the posterior margin inwardly rounded; lateral edges red, black beneath and shining. Scutellum jet black. Elytra bright red, marked characteristically with six large black spots, two near the base, one on the elaval area, another on the corium, a smaller spot on the elaval suture, just before the apex, one larger at the apex, and the last on the middle of the elytron. Venation rather indistinct. Hind wings slightly lurid. Abdomen brown above, beneath black but reddish at base, the posterior edges of the segments red. Legs black at base, the tibia bright red and the tarsi black. Posterior tibiæ with the median spine well developed. Genitalia indistinct.

Habitat: Transvaal, Pretoria (Distant), Johannesburg, (Cruger, Brit. Mus.), Boksburg (Kaessner), Natal (Mansell Weale), Durban (Bell-Marley), Howick (Cregoe), Bechuanaland, Omaramba (Erikson), Kaffraria, (Castelnau, Oxford Mus.)

Tegwani (Brain), Debe Nek (Brain), Metabele Land (Oates, Oxford Mus.), Mashonahand (Salisbury, Marshall), Cape Colony (Mansell Weale), King Williamstown (Barrett). "Africa meridionalis occidentalis" (Stal).

B. Locris transversa Thunb.

Cercopis transversa, Thunberg. Hem. Rostr. Cap. 1. 4. (1832).
Monecphora phœnicoptera, Walk. List Hom. Brit. Mus. III. 676. (1851).
Monecphora fuscicollis, Stal. Ofv. Vet. Ak. Forth. 95. (1855).
Locris transversa, Stal. Hem. Afr. IV. 61. (1866).
Locris transversa, Dist. Ins. Transv. IX. 228. (1908).

Black with red on the head and thorax. Elytra red, yellowish towards the apices. Length 8.5 mm. Breadth 3.5 mm.

Head not as wide as the pronotum, rather sharply pointed; anterior and lateral margins of vertex red, black on the middle and posterior margins between the eyes. Eyes grayish black. Width at eyes a little longer than the length of the vertex. Face very tumid, the frons black with the carina red; numerous transverse furrows; clypeus bright red, rostrum long, black at the tip. Cheeks narrow, black.,with the edges red. Pronotum much wider than the head, the anterior margin straight, red; a large black transverse band behind the anterior margin, a median red band and the lateral edges red; posterior black; finely punctate and pubescent. Width about twice the length; length about one and a half times the length of the vertex. Sternum of thorax red. Scutellum very small, black, and very pubescent. Elytra bright red, the veins showing yellowish, towards the apical area lighter; hind wings brownish, paler towards the base, the veins brown, and red near the base. Abdomen above black, the posterior edges of the segments red; beneath black, red at base, and on edges of the segments. Genitalia of female red; the last ventral segment dark red, longer than the penultimate, and deeply emarginate. Legs dark red.

Habitat: Natal (Mansell Weale), Durban (Leigh, Oxford Mus.), Isipingo (Marshall), Delago Bay (Monteiro), Kaffraria (Stal), Cape Colony (Drege, Brit. Mus.), East London (Brain), Uitenhage (Oxford Mus.).

Locris rubida Stal.

Monecphora rubida Stal Ofv. Vet. Ak. Forh. 96. (1855).
Monecphora postica Stal Ofv. Vet. Af. Forh. 96. (1855).
Locris rubida Stal Hem. Afr. IV. 61. (1866).
Locris rubida Dist. Ins. Transv. IX. 228. (1866).

Color jet black, the elytra dark red, except the apical area. Black below. Length 10.5 mm. Breadth 3.5 mm.

Head very small, rounded anteriorly, the vertex black with a trace of red on the side margins before the eyes; length about equal to the width across the eyes, very pubescent. Face black, the frons very

tumid, with a median carina and numerous transverse furrows; a trace of red on the rostrum. Ocelli very small, eyes black. Pronotum strong, black, finely punctate, the lateral margins faint red, beneath black. Scutellum black, about one third the length of the pronotum, which is more than twice as long as the vertex. Elytra red, apices black. Hind wings smoky at apices, lighter towards the base. Abdomen above black, the posterior edges of the segments red; beneath black with red for the base and posterior edges of the segments. Female genitalia—last ventral segment not quite as long as the penultimate; pygofers rounded, short; ovipositor long. Legs black.

Habitat: Natal (Mansell Weale), Durban (Marshall), Kaffraria (Castelnau, Oxford Mus.), N. W. Rhodesia, Kambove (Neave), Cameroons (Escalera), Cape Province, Fort Beaufort (Brain).

Subf. Aphrophorida Stal.

Synopsis of Genera.*

A. Pronotum quadrangular.
Scutellum a little longer than broad: anterior margin at lobes of vertex acute: apices of elytra narrow.....**Cordia**

AA. Pronotum sexangular.
Scutellum a little alonger than broad; anterior margin at lobes of vertex sulcate.....**Philænus**
Scutellum much longer than broad; pronotum broader than the head. **Poophilus**

Genus **Cordia** Stal.

Head rounded or angularly rounded, with the anterior margin acute, at least to the lobes of the vertex. Front transversely striate. Lateral angles of the pronotum acute. Elytra suboblong, the apex a little narrow, and the lateral margins subparallel. At present this genus is only known from the Ethiopian Region (Distant).

Cordia peragrans Stal.

Cordia peragrans Stal. Hem. Afr. IV. 78. (1866).
Ptyelus peragrans Stal. Ofv. Vet. Ak. Forh. 97. 10. (1855).
Cordia peragrans Dist. Ins. Transv. IX. 223. (1908).

Grayish straw colored. Length 5.75 mm. Width 2–2.25 mm.

Head flat, brown in color, and covered with a fine gray pubescence, wider than the pronotum at eyes, and longer than half the length of the pronotum. Ocelli brown, as far apart from each other as from the eyes. Anterior margin of the head flat, rather sharp; two black spots on the face below the anterior margin of the head, and located midway between median sulcus and the antennæ. Face densely pubescent. Rostrum black. Eyes dark steel gray. Pronotum flat, twice as broad as its length, finely punctate, the punctations arranged in fine rugæ, very

*Adapted from Stal.

pubescent. Distinct longitudinal median line, on the pronotum, and two irregular impressions on the anterior half located behind the eyes; two more irregular marks, situated towards the median line, also on the anterior half. Scutellum brown, with gray pubescence, not quite as long as the pronotum. Sides of thorax brown. Elytra for the most part gray, brownish at the base; veins distinct brown; a black distal spot behind the middle, situate at the anastomosis of two cellular areas; apex of elytron almost transparent. Abdomen above dark brown to black, the margin lighter; beneath brown with a tinge of red; legs light brown, tips of tarsi black. Genitalia-female-last ventral segment short, notched at the middle; plates longer than last ventral segment, narrow; pygofers short and stout, with a distinct reddish tinge, very pubescent; ovipositor black, much longer than the pygofers.

Habitat: Caffraria (Stal), Cape Province (Stal), Transvaal Province (Distant), Zoutpansberg (Kaessner) and Selati River (Albany Museum).

Cordia albilatera Stal.

Cordia albilatera, Stal. Hem. Afr. IV. 79. (1866). Distant Ins. Transv. IX. 223. X. Tab. XXII. Fig. 9a. (1908–10).
Ptyelus albilatera Walk. List Hom. B. Mus. 723. (1851).

Grayish stramineous, covered with a pale down. Length 5.5. mm. Breadth 2 mm.

Head brownish not pubescent, a little wider than the pronotum at the eyes; vertex not quite as long as the pronotum. Ocelli closer to one another than to the eyes; anterior margin of head angularly rounded. Eyes long, wide, steel gray in color. Face a dark brown, darker than the vertex, pubescent; clypeus lighter in color, lorae brown, cheeks much lighter. Pronotum twice as wide as its length flat, finely punctate, pubescent, and rugose on the posterior half; anterior margin well rounded; faint irregular impressions on the anterior half, midway between the median line and the lateral margins. Scutellum much longer than broad, with a distinct whitish longitudinal ridge on the middle; apex sharply pointed. Elytra brownish, cinereous, very pubescent, the veins showing as dark brown ridges; apices well rounded, costal margin grayish; small black distal spot behind the middle situate at the anastomosis of two cellular areas; punctulate. Abdomen above black, the posterior edges of the segments and the lateral margins yellowish brown; beneath light brownish yellow. Male genitalia—last ventral segment rather short, slightly notched at middle; plates longer than the ultimate ventral segment; pygofers rather long, and narrow, the tips blackened. Legs light yellowish brown, the tips of the spines black.

Habitat: Transvaal, Zoutpansberg (Kaessner), Natal (Mansell Weale), Cape Colony (Stal), Grahamstown (Albany Mus.).

Genus **Philaenus** Stal.

Head angular, anterior margin of lobes of vertex obtuse, sulcate; apex of clypeus a little produced; rostrum two-jointed, reaching beyond the middle coxæ. Elytra oblong in general outline, the side margins subparallel, with the apices rounded.

This genus is widely distributed. In his work on the Transvaal forms, Distant includes Philaenus under Ptyelus.

Philænus caffer Stal.

Ptyelus caffer, Stal Ofv. Vet. Ak. Forh. 250. (1855).
id. Eug. Resa. Hem. 287. (1858).
Ptyelus caffer, Dist. Ins. Transv. IX. 221. (1908).
Philaenus caffer, Hem. Afr. 78. IV. (1866).

General color varies, usually a grayish straw or yellowish. Length 5-5.5 mm. Breadth 2 mm.

Vertex produced, rounded at apex, the disc flat, densely pubescent, the length longer than half the distance between the eyes and equal to about more than one-third of the width across the eyes. Frons swollen, convex, a little wider at the base than next the vertex, the sides subparallel, about twice as long as the width next clypeus; the latter is roughly triangular in shape, and sharply produced; loræ almost as wide as the clypeus, genæ angular; point of insertion of the antennæ dark brown; tip of rostrum black. Pronotum lighter in color than the head, covered with a grayish pubescence, with four blackish spots on the anterior half, two rather distinct, alongside the median line, and the other two indistinct, near the lateral margins. These spots, however vary in different forms. Anterior margin broadly rounded between the eyes; length a little longer than the vertex and longer than half the width of pronotum. Surface of pronotum finely punctate. Scutellum a little more than half the length of the pronotum. Elytra lighter than rest of the body, the veins distinct, showing as brown ridges, six apical cells, and three anteapicals, the middle cell of the latter shorter than the other two; apices rounded, a little narrower than on middle. Abdomen above brownish, beneath brownish black, in some cases pure black. Legs light yellowish. Genitalia—female; last ventral segment rather short, pygofers oval, broad, not as long as ovipositor. Male ultimate ventral segment twice as long as the penultimate, the posterior margin concave, plates a little longer than last segment.

Described from four males and one female.

Habitat: Cape Colony (Stal), Cape Province (Distant), Darling, C. P., (Mally).

Philænus hottentoti n. sp.

General color yellowish brown, form similar to P. caffer Stal, but a little stouter. Length 6 mm. Width 2 mm.

Head yellowish, broad; vertex angularly rounded, two black spots on the anterior margin, located on the middle close to one another; posterior

margin slightly convex on the middle, giving the ocelli a raised appearance; thin black transverse line on middle extending to margin of lobes. Eyes well rounded, whitish mingled with brown; ocelli dilute brown. Length of vertex less than half the distance between eyes, and equal to about one-fourth of the distance across the eyes. Face strong, of a yellowish color, covered with a dense grayish pubescence; frons distinct yellow, decidedly convex, traversed by numerous dark yellow arcs; two black spots near the margin of the vertex, in line with those on the vertex. Frons three times as long as its width next the clypeus and twice as long as the latter. Clypeus broad next the frons, strongly produced at the apex; loræ small, about one-third the width of the clypeus; genæ small, inwardly rounded; rostrum long, the last joint black. Antennæ deeply inserted, basal joint stout. Thorax well developed, darker in color than the vertex, finely punctate, and pubescent, twice as broad as long and two and a half times as long as the vertex; anterior margin angularly rounded, side margins short, rounded inwardly; posterior margin concave; scutellum longer than width at base, and half as long as the pronotum. Venter of thorax yellow except near the coxæ, where it is black. Elytra brownish, pubescent, the outer margins lighter; venation strong, of typical Philænus type. Abdomen above black, the margin somewhat yellow, beneath, brownish black, but possessing a grayish tinge owing to the pubescence. Legs a light yellowish brown. Genitalia—male last ventral segment a little longer than the penultimate, slightly concave on its posterior margin; plates long, about one and a half times as long as their width at base.

Described from one male.

Habitat: Cape Town. (Mally).

The above species may be distinguished from P. caffer Stal, by the darker color, the shorter vertex and the elytral venation.

Genus **Poophilus** Stal.

Head roundly subangular, disc of vertex flat, vertex narrower than the pronotum, the anterior margin acute; frons slightly convex; clypeus produced at apex, reaching beyond the fore coxæ. Ocelli almost as far from the eyes as from one another. Pronotum transverse, sixangled, the lateral margins short, and the anterior broadly rounded. Scutellum longer than broad. Elytra densely punctate, apical area narrower and rounded, the side margins straight as far as the apex.

Poophilus terrenus Walk.

Ptyelus terrenus Walker List Hom. Brit. Mus. III. 709. (1851).
Ptyelus umbrosus Stal Ofv. Vet. Ak. Forh. 97. (1855).
Poophilus umbrosus Stal Hem. Afr. IV. 74. (1866).
Poophilus terrenus Dist. Ins. Transv. IX. 222. (1908).

Color tawny brown. Length 10 mm. Breadth 3.25 mm.

Vertex strong, the anterior margin sharp; length not quite equal to the width between the eyes; ocelli colorless, closer to one another than to the eyes. Eyes oval, elongate, brown, prominent; anterior of head rounded. Face strong, black, interspersed with yellowish spots on the margin, slightly convex, flat on middle, with numerous transverse furrows; frons with some yellow irregular spots; clypeus yellowish, long, produced, heart-shaped, about two-thirds of the length of the frons; rostrum long, black at the tip; loræ long, very narrow; cheeks narrow next the loræ wider beneath the eyes. Pronotum dull brown, the anterior margin broadly rounded, side margins very acute, posterior somewhat concave; flat on top, with two small depressions alongside the median line; length of pronotum greater than the vertex, the breadth about twice the length. Scutellum much longer than broad, the apex sharp; venter of thorax black, the pro-, meso-, and metapleura with yellow borders. Elytra dull brown, with many irregular black markings, the margins lighter; venation distinct, apex of elytra sharply rounded. Abdomen yellow beneath, with black for the base. Legs yellowish with brown spots. Genitalia—female; last ventral segment not quite as long as the penultimate; pygofers yellow, broad, flattened, twice as long as their width at base; ovipositor brown, sharp, a little longer than the pygofers.

Habitat: Transvaal, Pretoria (Swiestra), Lydenburg, (Krantz), Zoutpansburg (Kaessner), Johannesburg (Fry), Water val-onder (Ross), Natal, Durban (Mansell Weale), Isipingo (Marshall), Delagoa Bay (Junod), Kaffraria (Stal), Wynberg, C. P., (Mally).

Superfamily Jassoidea.

The members of the Superfamily Jassoidea may be recognized by the character of the tibiæ, which are prismatic in shape, and armed with a row of spines on their posterior margins.

Synopsis of Families.

The following key, taken from Osborn's work on the Jassoidea of Maine, will illustrate the main characters of the subfamilies.

A. Elytral nervures forking on the disk.
  b. Ocelli located on the disc of the vertex..... **Tettigoniellidæ**
  bb. Ocelli located on border of vertex between vertex and front.. **Jassidæ**
  bbb. Ocelli located on front distinctly below border of vertex.... **Bythoscopidæ**

AA. Elytral nervures forking at base and running to apex of elytra, ocelli usually wanting..... **Typhlocybidæ**

Besides the works of Walker and Distant, the more important publications on the South African forms are those of Melichar, Signoret, Distant and Burmeister.

FAMILY BYTHOSCOPIDÆ.

The general characters of this family are well marked, the most conspicuous being the position of the ocelli, which are located on the front below the vertex. As a rule the vertex is short and wide, and with the eyes, is generally or often broader than the pronotum. Definite striations are frequently observed on the pronotum. The elytral venation is frequently obscure. The appended synopsis of genera will indicate the main characters of the genera.

Like the Typhlocybidæ, little is known about the South African representatives of this family. The writer is fortunate in being able to describe a member from each of four of the most prominent genera.

Synopsis of Genera.*

A. Antennae inserted in a deep cavity beneath a ledge.
  b. Striation of the pronotum transverse.
    c. Side margins of the pronotum sharply keeled, of moderate length..... **Macropsis**
  bb. Striation of pronotum running obliquely from the middle of its front margin to the hinder angles..... **Pediopsis**
AA. Antennae inserted in a feeble cavity, their base free.
  b. Head with the eyes wider than the elytra at the base, membrane with an appendix..... **Idiocerus**
  bb. Head with the eyes as wide as the elytra at base, no appendix.. **Agallia**

Genus **Macropsis** Lew.

Macropsis subolivaceus Stal. (Pl. IV, Fig. 1).

Bythoscopus olivascens, Stal. Ofv. Vet. Ak. Forh. I. 99 (1855).
Macropsis subolivaceus, Stal. Hem. Afr. IV. 127. (1866).
Macropsis subolivaceus, Mel. Beit. Z. Kenn. Hom. Deutch Oost-Afrika 297. (1905).

General color olivaceous. Length, 5 mm. Breadth, 2 mm. Vertex yellow, very short; well rounded anteriorly and distinctly striated. Eyes steel gray, small; width between the eyes four times as long as the vertex. Face short, two-thirds as long as its width across the eyes; frons yellowish. Clypeus greenish, one and one-half times as long as its breadth; lorae prominent, not quite as wide as the clypeus. Ocelli colorless or sanguineous. Pronotum yellowish green, with strong transverse striations on its posterior half, and smaller striations on the middle of the anterior half, but not reaching the margin; about three times as long as the vertex, and about half as long as the width of the pronotum; anterior margin well rounded, the lateral margins of moderate length; posterior half broader than the anterior, being the widest part of the body; convex anteriorly and laterally. Scutellum a little longer than broad tapering to a point; about as long as the pronotum; olivaceous in color, but with two large brown spots at the basal angles, and a

*Adapted from Osborn.

curved depressed line on the middle, behind which are pronounced transverse striations. Elytra yellowish green, with a fine punctation; transparent; venation indistinct, some of the veins being indicated by minute papillæ; appendix well developed. Abdomen above yellowish, beneath greenish. Legs greenish, posterior tibiæ very strong. Genitalia—female; last ventral segment more than twice as long as the preceding, convex, with the posterior margin very slightly concave; pygofers strong, about three times as long as the last ventral segment, convex laterally; widely separated on the middle, and narrowing at the tip; ovipositor equaling the pygofers in length. Male—last ventral segment about three times as long as the penultimate, strongly produced to a rounded point pygofers rounded, not as long as the ultimate ventral segment.

The nymphs of this species are dull, greenish brown in color, covered with numerous fine hairs or spines, and have a broadly oval appearance. The vertex is longer than in the adult, while the pronotum is rectangular. The body is large, rounded and very hairy.

Habitat: Cape Town (Mally), Rondebosch (Stal), Sierra Leone (Stal), Tanga (Melichar).

Genus **Pediopsis** Burm.

Pediopsis capensis sp. n. (Pl. IV, Fig. 2).

Form broad and stout, general color greenish yellow, covered with a fine brown spotting. Propleura with a black spot. Length 4.5 mm.; width at pronotum 2 mm.

Vertex very short, viewed from above, narrow at middle, but becoming slightly wide towards the eyes; greenish in color, with the brown spots rather obscure. Eyes steel gray, a little wider than the pronotum, having a flattened oval appearance. Face yellowish green, broad and of moderate length, with coarse though shallow rugulæ and punctulations; frontal suture prominent; frons strong, wide between the eyes; tapering gradually to the clypeus; the latter short, broad, and prominent, wider next the frons than at apex; loræ long and narrow; cheeks of moderate width, slightly depressed beneath the eyes; ocelli colorless. Pronotum olivaceous, with brown spots, prominent; rugæ conspicuous, decidedly oblique; anterior margin broadly triangular, lateral of moderate length, posterior slightly concave; length about two-fifths of the breadth; disc convex on posterior half. Scutellum large, of a yellowish color, with two large, round brown spots located at the basal angles, about equal to the pronotum in length; a short transverse line on the posterior half. Venter of thorax yellow, black spots on the pro- and metapleura. Elytra yellowish, with numerous brown spots; at apex of the clavus are two brown markings, which when the wings are at rest, give a distinct spot, different from the general marking. Venation distinct, six closed cells on the corium, one basal, two discal, and

three anteapical; membrane composed of fine apical cells. Wings very delicate, membranous, the supernumerary cell absent. Abdomen above greenish, short, compressed, beneath yellowish. Legs brownish, tarsi three jointed, the basal joint almost as long as the second and third combined. Male genitalia; last ventral segment twice as long as the penultimate; plates as long as the ultimate ventral segment.

Described from two males.

Habitat: Cape Flats, C. P., (Mally).

Genus **Idiocerus** Lewis.

Idiocerus hewitti. sp. n. (Pl. IV, Fig. 3).

Yellowish green, with two black spots on the anterior margin of the vertex and two spots, also black, on the base of the scutellum. Length, 5.5 mm. Width across eyes 2.25 mm.

Vertex broad and stout, with the eyes very prominent, greenish in color; yellow halos around the black spots, which are situated nearer the eyes than the median line. Eyes very large, brownish black; ocelli colorless, located nearer the eyes than the middle. Face broad, a little broader than its length; frons large, convex, yellow with lighter transverse bands on the middle; clypeus a little larger than its breadth; loræ prominent; cheeks somewhat lighter than the rest of the face. Pronotum long, with distinct transverse striations. Scutellum yellow, a little longer than the pronotum, with two round black spots on the base. Elytra faint yellow, with the venation rather indistinct; apical cells prominent the sectors set with minute tubercles. Abdomen above black, beneath greenish yellow; lateral margins green. Legs light yellow to whitish. Female genitalia: dull green in color, the last ventral segment, more than twice as long as the penultimate, notched at the middle, and slightly concave on its posterior lateral margins; pygofers large, stout, shorter than the ovipositor, which is broader at the tip, than at base.

Habitat: Grahamstown, C. P., (Hewitt).

The above species was described from two females sent to me by Mr. J. Hewitt, Director of the Albany Museum, at Grahamstown.

Genus **Agallia** Curtis.

Agallia nigrasterna sp. n. (Pl. V, Fig. 1).

Form similar to A. novella Say. Color light yellowish brown, the elytra whitish. Length of male almost 4 mm. Breadth 1.25 mm.

Vertex yellow, brownish on the middle, short, about one-fourth of the length of the pronotum; two large, round, black spots on the anterior margin; and two faint fuscous bands on the middle, between them; width of vertex across eyes greater than the pronotum. Face brownish

white, the frons brownish on the middle and sides, with a brown band extending from below the ocelli to the anterior margin of the head; much wider than the clypeus, which is oval in shape, yellowish, with the sides marked brown; loræ white, not as wide as the clypeus. Cheeks white, strong and broad. Ocelli colorless. Black markings beneath the antennal pits. Pronotum strong, brownish on anterior, whitish on posterior half with two large black spots near the posterior margin; irregular brown markings in advance of these, and a brown median band. Pronotum almost twice as wide as its length, the anterior margin rounded, and the posterior broadly rounded towards the sides; convex above. Scutellum yellow, with a brownish semi-circular furrow on the anterior half, not as long as the pronotum; apex tapering to a fine point. Thorax beneath black. Elytra gray, semi-transparent, the veins distinct, showing as brown lines. Middle anteapical cell much larger and longer than the other two; only three apical cells present. Abdomen above yellow, black at the base, beneath light yellow. Legs light yellow to whitish. Genitalia: male—last ventral segment a little longer than the previous ones; valve strong, three times as long as the ultimate ventral segment, broadly triangular in shape, rounded at apex; plates triangular, about equalling the valve in length. Pygofers not as long as the plates, yellowish ventrally, black dorsally.

Described from two males.

Habitat: Cape Town (Mally).

This species may be easily distinguished from A. novella Say. by the size and shape of the pronotum. In the former the pronotum is much larger and more convex than in the latter. Further the black spots on the pronotum of A. novella are located nearer the middle than in this species.

Agallia cuneata sp. n. (Pl. V, Fig. 2).

Form thin and slender with the posterior end of the body distinctly wedge-shaped. Color light pink, obscured in parts by a white incrustation; large round, black spots on vertex and pronotum. Length 3.5 mm. Breadth scarcely 1 mm.

Vertex small, well rounded, pinkish, the black spots on the anterior margin surrounded by yellowish halos; length about one-fourth as long as the pronotum; anterior margin rounded. Eyes yellowish, ocelli black Face narrow, a little longer than broad; frons whitish, with brown across the middle, and on the sides to the clypeus; genæ almost straight margined from clypeus to the eyes; loræ rather long and narrow, not as wide as the clypeus, which is short and oval, its length about one-fourth of the frons; sutures marked indistinctly with brown in parts. Pronotum whitish pink, about one and a half times as broad as its length, and not as wide as the vertex across the eyes; convex above both anteriorly and laterally; anterior margin rounded between the eyes, side margins of

moderate length; two black spots near the posterior margin, large and round. Scutellum whitish, about as long as the pronotum. Pro-, meso- and metapleura black. Elytra covered with a whitish incrustation, venation distinct, the veins indicated in part by brownish lines; apex of elytron rather sharply rounded. Four apical cells, and two ante-apicals, the inner ante-apical being much larger and longer than the other. Abdomen above blackish gray, the borders and ventral surface yellow. Legs dirty white. Genitalia: female—last ventral segment about one and a half times as long as the penultimate, the posterior margin almost straight, except for a small niche on middle; pygofers about two and a half times as long as the last ventral segment, and longer than their width at base; ovipositor longer than pygofers, black at the tip.

Described from one female.

Habitat: Cape Town, C. P. (Mally).

FAMILY TETTIGONIDÆ.

The family Tettigonidæ is easily recognized by the position of the ocelli which are located on the disk of the vertex.

Subfamily Gyponinæ Berg.

Genus **Penthimia** Germ.

Body oval; head obtuse, the anterior margin rounded. Pronotum frequently longer than the vertex, sometimes transversely striated. Scutellum a little broader than long.

Penthimia bella Stal.

Penthimia bella Stal. Hem. Afr. IV. 108. (1866).
Penthimia bella Stal. Ofv. Vet. Ak. Forh. 98. 2. (1855).

General color from above black intermixed with brown and dirty white, beneath black and brown. Length of female 4.5 mm. Breadth 1.75 mm. Vertex yellowish white with irregular brown markings arranged along a median line; obtusely angular, the length not as great as the width of the head between the eyes; anterior of head sharply rounded. Ocelli brown, eyes black. Face black, except the brown clypeus; sutures distinct; clypeus small, about one-fourth of the length of the frons. Pronotum a mottled brown, black and white; longer than the vertex, slightly convex on the anterior half, the lateral margins rather short. Scutellum yellowish with brown markings at the basal angles, about two-thirds as long as the pronotum. Elytra whitish but with a mottled appearance due to the brown and black; a few clear spaces in the anteapical cells, some hyaline areas on the corium, and middle of costal margin. Abdomen above brownish, lighter ventrally with the borders yellow. Genitalia: female—pygofers large, yellow with bluish marks, convex and very spiney; last ventral segment more than

twice as long as the penultimate, inwardly rounded on the posterior margin, and slightly produced on the middle; ovipositor large, longer than the pygofers.

Habitat: Rondebosch, C. P. (Stal: Mally).

Penthimia vinula Stal. (?)

Penthimia vinula Stal. Hem. Afr. IV. 108. (1866).
Penthimia vinula Stal. Afr. Vet. Ak. Forb. 98. 2. (1855).
Penthimia vinula Distant. Ins. Transi.

Form and appearance of P. bella Stal. Color shiny black mingled in parts with brown and white. Length 4 mm. Breadth 1.75 mm. Vertex white but with black markings which are symmetrical along a median line; length not equal to the width between the eyes; convex anteriorly, the margin obtuse. Eyes large, chocolate colored, ocelli black. Face strong, the frons prominent, about three times as long as the clypeus; loræ about as wide as the clypeus; cheeks large; two large prominent white spots on the face above the region between the eyes. Pronotum black with many small white spots; a little longer than the vertex. Pronotum and vertex transversely striated. Scutellum black over the major part, with a few white spots at the base, a white spot at the apex, and two large brown marks on the middle. Elytra fuscous black; claval area with few white spots; corium with a clear area near the base of the costal margin, a circular clear space at the apex of the claval suture and three distinct clear spaces on the area of the anteapical cells. Abdomen brownish black above, black on the venter, the edges of the segments showing as white lines and the margin a little lighter than the remainder. Male genitalia: last ventral segment black on the middle, yellow at the borders, about equal to the penultimate in length; valve yellowish brown, not as long as the ultimate ventral segment; plates black, longer than the valve, the tips sharp; pygofer longer than the plates, black.

Habitat: Cape Town (Mally), Transvaal, Pretoria (Distant), German East Africa: Amani, Bomole (Melichar).

This species varies from the P. vinula figured by Distant, in having white on the vertex, pronotum and middle of the elytral disk.

FAMILY JASSIDÆ.

The true Jassids are characterized by the position of the ocelli, which are located on the anterior margin of the vertex where it merges into the frons. The appended synopsis of tribes, taken from Van Duzee, best illustrates the main characters.

The family is perhaps better known than any other of the Jassoid division and the number of described species is far in excess of the Bythoscopidæ and Typhlocybidæ.

Synopsis of Tribes.

Anterior edge of the head thin and sharp, or more or less foliaceous....**Dorydini**
Anterior edge of the head sometimes acute, but generally obtuse or rounded, never thin and foliaceous.....**A.**
A. Elytra with two transverse nervures between the first and second sectors of the corium.....**Deltocephalini**
Elytra with but one transverse nervure between the first and second sectors of the corium.....**B.**
B. Elytra without a series of anteapical areoles or with but one, formed by the forking of the outer branch of the first sector; vertex subquadrate, the hind and lateral margins elevated, before feebly arcuated, with the edge strongly rounded or produced and tumid before with an obtuse apex.....**Jassini**
Elytra with a series of (generally three), apical areoles.....**C.**
C. Outer branch of the first sector of the elytra with two forks evident..... **Athysanini**
Outer branch of the first sector of the elytra with its outer fork obsolete or nearly so, anterior edge of the head well rounded, vertex but little, if at all longer on the middle than next the eye..... **Cicadulini**

Tribe Dorydini.

Genus **Cephalelus** Perch.

Cephalelus—Percheron in Guer. Mag. Zool. ii, Classe IX, (1832).
Dorydium—Burm. Handb. Ent. ii, 1, 106, (1839).
Burm. Gen. Quaedam. Insect i, (1838).
Cephalelus—Signoret, Ent. Soc. Fr. 504, 259, (1879).
Kirby, Trans. Ent. Soc. Lond, 412, (1894).

Head long, narrow, very strongly produced; vertex long, pointed, the sides rounded, more than three times as long as the width, face large, merging into the vertex; clypeus heart-shaped. Eyes lateral, elliptical. No ocelli. Antennæ short, the basal joint large and cylindrical, the second long, the third subcylindric. Pronotum transverse, the lateral margins of moderate length. Elytra corneous, punctulate, the apices rounded. Tibiæ without spines. Abdomen elongate, the males much shorter than the females.

Cephalelus infumatus Perch. (Pl. VI, Fig. 1).

Cephalelus infumatus Perch. in Guer. Mag. Zool. ii. Classe IX. pl. 48. (1832).
Dorydium paradoxum Burm. Handb. Ent. ii. 106. (1839).
Cephalelus infumatus Walk. Cat. Hom. Brit. Mus. 637. (1851).
Cephalelus infumatus Amy. & Serv. Essai sur les Jassides. 258. (1878).
Distant Ins. Transv. X. 241. (1910).

General color dark red to brown or yellowish brown in dried specimens. Length of females 11.75 mm. to 12.75 mm. Average length of twelve females 11.95 mm. Length of males 9.25 to 10.25. Average length of thirteen males 9.35 mm. Breadth 1.5 mm.

Female—Head dull red to brown above, with an indistinct line along the middle of the vertex, extending from the anterior margin, to a little before the eyes; beneath dark red with a broad yellowish band running along the middle, rather narrow at the anterior, but widening towards the posterior margin. Vertex about four times as long as its breadth;

with two dull red spots a little in advance of the eyes; finely punctate, and about five times the length of the pronotum. Eyes dark green to black, rather large. Ocelli absent, but two small depressions are indicated, where one would expect the ocelli. In his original description Percheron noted the presence of ocelli, but later Burmeister drew attention to the fact that these were mere depressions. Antennæ short, sharp at the distal end, inserted in deep pits. Facial sutures distinct; genæ yellowish, rounded; clypeus large, a little longer than broad, tapering gradually to the rostrum. Pronotum red, darker at the sides; a longitudinal line along the middle. Scutellum shorter than the pronotum. Elytra dark red, broadly oval in shape, densely punctulate, the punctation arranged in definite series; shorter than the abdomen. Abdomen above red, beneath light brown to yellowish. Genitalia: last ventral segment small and distinctly notched and grooved on the middle, not as long as the penultimate; pygofers long and narrow, widely separated at the base, becoming closer on the middle, and separating again at the tip. Ovipositor long, thin, much longer than the pygofers, its length about 3.5 mm. Legs light brown, the femurs stout.

Male—Face with a distinct yellow band along the middle; elytra much longer than the abdomen, light brown along the margin of the corium. Genitalia, last ventral segment not quite as long as the penultimate, valve about as long as the last ventral segment, triangular in shape; plates long, rounded at the tips, about twice as long as the valve; pygofers a little shorter than the plates.

This interesting insect is one of the most unique in Southern Africa. According to the literature it seems to be scarce in collections, but in the material on hand it is quite abundant. The original description was based on a single specimen, the habitat of which was unknown until later it was identified with the Cape. Burmeister stated that he had only seen two specimens, one at Berlin and the other at Hamburg, and he mentions the habitat as the Cape of Good Hope. As far as the writer is aware, this is the only complete description of both male and female that has been published.

An interesting case of protective mimicry is recorded for Cephalelus infumatus, and this probably accounts for its scarcity in collections. According to Professor Osborn, "The protective feature comes in from the fact that the aborted leaf-sheaths on the stem of the plant form sharp spines occurring at intervals along the length of the stem, and these are perfectly reproduced in the form and color of the insect. So close is the resemblance that when a number of the spines are mounted separately alongside of the insects, it is very difficult to distinguish them without the most careful scrutiny. When the specimens were first received, I had looked them over some time before noticing that a number were not insects at all, but simply spurs and had there not been one mounted with a fragment of stem along with an insect beside it, I might have taken a much longer time to make the discovery. I have shown the set to a number of individuals, who have taken quite a little time to make the same discovery."

"According to Mr. Mally the insect lives on the rush Dovea tectorum Masters, the spurs of which are mimicked. I may mention that the stems are green, while the aborted leaf-sheaths are dark brown."

Tribe Deltocephalini.

Genus **Deltocephalus** Burm.

Body oblong or oval, elongate; head with the eyes as wide as the pronotum, pointed in front; ocelli on margin between vertex and front. Vertex flat or slightly convex at the lateral margins, more or less angularly produced in front. Inner sector of elytra forked twice, three anteapical cells present. In the Brachypterous forms there is a decided reduction in the number of veins.

Deltocephalus breviatus sp. n. (Pl. VI, Fig. 2).

General color yellowish green, Brachypterous form. Length 2.75 mm. Breadth scarcely 1 mm.

Male—Vertex yellow, with a median line extending from the posterior margin to a little beyond the middle; length a little more than twice the width between the eyes; anterior margin sharply pointed, acutely rounded; eyes greenish white, large, prominent, extending backward beyond the anterior edge of the pronotum. Ocelli small, colorless, located near the eyes. Face yellow, the frons traversed by six to eight brown ares; length of entire face about equal to the width across the eyes; frons more than twice as long as its width next clypeus, and more than twice as long as the clypeus, which is one and one-half times as long as it is broad and is parallel margined. Lorœ prominent, cheeks broad and strong. Pronotum greenish-yellow above, black beneath; broad, not as long as the vertex, the anterior margin rounded between the eyes. Scutellum small, yellowish green, half as long as the pronotum. Elytra yellowish, transparent, short, extending to the penultimate dorsal segment of the abdomen; venation rather indistinct, apices of elytra broadly rounded. Abdomen above yellowish, the first two segments black on their lateral margins; beneath black, with yellow borders. Legs light yellowish, the coxæ black. Genitalia; last ventral segment very small, less than half as long as the penultimate; rounded broadly on its posterior margin, black on the anterior, and light yellow on the posterior; valve black, more than twice as long as the last ventral segment, rounded at its apex; plates long triangular, yellow, with occasional black spots, tips rounded. Pygofers large, longer than the plates, very spiny, the spines forming a crown at the tip; ventral color black at base, yellow at the tip; dorsal yellow, but black at the bases of the lateral margins and the tip black.

Female—General color the same as the male. Head somewhat sharper and more pointed. Genital apparatus, last ventral segment black, a little larger than the penultimate, sinuate on the middle, the posterior margins curving slightly to the sides; pygofers yellowish, more or less colored with brown and black, widely separated at the base, but converging towards the tip; the amount of brown coloration of the pygofers varies but as a rule is confined to the basal half; ovipositor

black, strong, equaling the pygofers in length; ventral tip of pygofers black, the spines strong, forming the crown as in the male.

Described from three females and seven males.

Habitat: Cape Town, C. P. (Mally).

Deltocephalus aristida sp. n. (Pl. VI, Fig. 3).

General color brownish black. Form long and slender. Length of female 4 mm. Breadth scarcely 1 mm.

Head brownish black, prominent; disc of vertex flat, slightly rounded towards the sides, the apex very pointed; a median line extending from the posterior margin to the tip of vertex; length greater than the width and equal to about half the width across the eyes. Face strong, longer than its width; frons black with faint yellowish arcs, three times as long as its width next to clypeus, and two and one-half times as long as the latter; clypeus black, with a faint yellowish tinge, one and a half times as long as its width next to the frons, sides almost parallel, apex rounded; loræ prominent, half as wide as the clypeus; genæ well rounded, depressed beneath the eyes, black with a narrow yellow border. Point of insertion of the antennæ deep. Face, vertex, prothorax and scutellum finely punctulate. Pronotum well rounded between the eyes, black with five indistinct yellowish longitudinal lines, one on the middle and two on either side, near the lateral margins; posterior margin slightly concave, lateral margins somewhat convex, short; length of pronotum not quite as long as the vertex; sides and venter black with a bluish tinge. Scutellum black, about equal to the pronotum in length. Elytra brownish, becoming lighter at the apex of the corium; veins showing as lighter lines; appendix strong; abdomen above blackish brown, beneath black; legs lighter in color than the rest of the body. Genitalia, Female—ultimate ventral segment about twice as long as the previous, strongly produced on the middle, the posterior margin rounded, inwardly, the apex somewhat convex; pygofers strong, widely separated at the base, and closer near the tip, three times as long as the last ventral segment; color brown with a yellowish tinge; ovipositor wide, a little longer than the pygofer.

Described from one female.

Habitat: Cape Town, C. P. (Mally).

Tribe Athysanini.

Genus **Athysanus** Burm.

Body robust, somewhat rounded at the sides. Head with eyes generally wider than the pronotum, obtuse in front. Vertex slightly produced; ocelli located near the eyes on the margin between vertex and front. Pronotum short, transverse, sometimes striated. Elytra with inner sector forked twice, three anteapical cells and frequently five apicals. Ovipositor short, little if any longer than the pygofer.

Athysanus capicola Stal. (Pl. VII, Fig. 1).

Thamnotettix capicola Stal Hem. Afr. IV. 123. (1866).
Athysanus capicola Stal. Ofv. Vet. Ak. Forh. 99. 2. (1855).

General color yellowish or dirty white. Length of male 5 mm., female 5.5 mm. Breadth 1.75 mm.

Vertex rather short, not produced, whitish in color with a strong black or brown transverse band across the middle; prominent and running from eye to eye; length of vertex about equal to one-half times the width between the eyes; anterior margin of the head obtusely rounded, the lateral margins sloping, slightly convex on disc with rather indistinct striations. Eyes dull green, large. Ocelli located nearer the eyes than to the middle, dilute red. Face strong, yellowish, with many dark yellow transverse arcs on the frons; frons a little longer than its breadth, much wider than the clypeus, and about two and a half times as long. Cheeks and loræ lighter in color than the frons, the latter as wide as the clypeus; clypeus produced, twice as long as its width, the sides subparallel and the apex rounded; rostrum rather long. Pronotum dilute yellow with numerous small brown spots; an irregular row of brownish spots on the anterior half arranged transversely; length of pronotum greater than that of the vertex; width more than twice the length. Scutellum yellow, not quite as long as the pronotum, transversely striated at the apex. Elytra equaling the body in length, overlapping at the tips; color yellow, the veins showing as brown lines. Appendix strong. Abdomen above yellow, with small black spots on the lateral margins of each segment; beneath yellowish in females, brownish in males. Legs light yellow to whitish. Genitalia female: last ventral segment more than twice as long as the penultimate, notched at the middle, convex on the surface; pygofers long and slender, about two and a half times as long as their width at base, and three times as long as the last ventral segment; ovipositor strong, longer than the pygofers, sharp at the tip. Male: last ventral segment, a little longer than the previous one, brownish black in color; valve a little longer than the last ventral segment, plates narrow somewhat rounded at the tip, about twice as long as the valve; pygofers not quite as long as the plates.

This jassid is by far one of the most common in Southern Africa and has been taken in great numbers on grasses and forage crops in the Eastern Province of Cape Colony. It is undoubtedly of some economic importance, not only on account of its numbers, but on account of its wide distribution throughout the provinces. It exists under a variety of different conditions, ranging from tropical, through subtropical to temperate regions, judging from the fact that it has been taken commonly in German East Africa, the Island of Mauritius, Senegal, Natal and the southernmost portions of the Cape.

It is closely related to Athysanus exitiosus, a form which is most common and of great economic importance in the United States. Morphologically the two agree in many characters, and show similar variations. The North American form is undoubtedly a tropical one, which has gradually migrated from Central America to the north, its food habits changing with time and the propagation of cereal crops. Similarly the African form is probably of tropical ancestry, and has gradually spread from the equator southward till it reached the coastal region. The cases are parallel in point and are of interest on that account. While it may seem a far stretch of imagination to consider a common ancestry for the two species, yet such a conjecture would seem feasible, in view of the land connection which once existed between Africa and South America.

Habitat: Rondebosch, C. P. (Stal), Cape Town (Mally), Grahamstown (Cogan), De Aar, C. P. (Cogan), Mauritius (Stal), German East Africa, Amani, Sigital, Tanga, Bomole, Kiboteni (Melichar).

Athysanus æthiopica sp. n. (Pl. VII, Fig. 2).

General color greenish white, with a varying amount of brown or black on the face. Length 3. mm. Breadth about 1 mm.

Female: Vertex whitish with an irregular black marking at the apex, not quite as long as the width between the eyes; ocelli colorless, eyes greenish. Face yellow, but prominently marked with black; frons yellowish white, except for the strong black arcs, about twice its length next the clypeus; loræ yellow with the sutures brown to black; cheeks yellowish green; clypeus one and a half times as long as its width next the frons, yellow with brown on the middle; rostrum brownish black. Pronotum greenish, broadly rounded between the eyes, a little shorter than the vertex, faintly transversely striated; scutellum yellowish, not quite as long as the pronotum. Sternum black. Elytra a little longer than the abdomen, semi-transparent, light greenish white in color. Abdomen above black with the borders yellow, beneath yellow but with black for the base and the middle. Genitalia: last ventral segment whitish, more than twice as long as the penultimate; posterior margin slightly curved inward and produced on the middle; pygofers long and slender, two and a half times as long as their width at base; ovipositor brown at the tip, a little longer than the pygofers; ovipositor brown at tip, a little longer than the pygofers.

Male: General color the same as female; the brown coloration is perhaps more prominent on the males. Black marking on the vertex not as evident. Abdomen entirely black on dorsal and ventral sur-

faces. Genitalia: last ventral segment black on middle, yellow at the sides; little longer than the penultimate; valve black at base, yellow on border, scarcely visible; plates whitish long, somewhat rounded at the tips; pygofer a little longer than the plates. Legs light yellowish white.

Described from four males and four females.

Habitat: Cape Town (Mally).

The species described above is subject to some variation in the distribution of the brown coloration of the face, vertex and abdomen. In some, the black marking on the vertex is absent, in others very prominent; in others the black on the face extends all over except for the middle of the frons and cheeks and loræ, while it may be wanting in some other specimens.

Athysanus eriocephalus sp. n. (Pl. VII, Fig. 3).

General color light yellowish to brownish. Length 4 mm. Breadth 1.5 mm.

Female—Color yellowish brown, with the vertex a dirty white, marked with irregularly shaped brown markings. Head strong, the vertex somewhat produced, with the anterior margin rather sharp, and the apex angular; length of vertex a third greater than the pronotum, and less than the width between the eyes, equalling about two-fifths of the total width across the eyes. Eyes black, prominent; ocelli located near the eyes. Face strong, the frons marked by numerous transverse brown arcs, about one and a half times as long as its width a little above the clypeus; the latter about one and a half times as long as its breadth, the margins subparallel; frons about two and a half times as long as the clypeus; loræ not quite as wide as the clypeus Pronotum a dirty white with brownish markings, narrow, about three times as wide as its length, the anterior margin broadly rounded, the lateral margins short. Scutellum not quite as long as the pronotum. Elytra yellowish white, with occasional brownish spots, veins showing as brown lines; brown spots on the middle anteapical cell, the first discal cell, and two on the second discal cell; margins well rounded. Abdomen above brownish black, beneath brownish yellow. Genitalia, last ventral segment about one and a half times as long as the penultimate; posterior margin deeply emarginate, color yellow, the pygofers brownish, much wider at the base than the tip. Ovipositor blackish, strong, a little longer than the pygofers.

Male—Lighter than the female, in fact a light straw color; elytra lighter, otherwise resembling the female. Genitalia: Last ventral segment brown on the middle, whitish yellow at the sides, almost one and a half times as long as the penultimate; valve small, semicircular, scarcely visible; plates yellowish brown, almost as long as last ventral segment; pygofer a little longer than the plates.

Described from two females and five males.

Habitat: Cape Town (Mally).

Athysanus cyclopia sp. n. (Pl. VII, Fig. 4).

General color dull brownish, with the elytra bluish gray; form short and broad. Length 3 mm. Breadth 1.25 mm.

Vertex brown, flat on the disk, the apex pointed and the margins sloping; small brown lines fringing the anterior margin running from the apex to the eyes; these arcs are continued over on the face. A small median line running from the middle of the posterior margin to the middle of the disk; length not equal to the width between the eyes, and about one-third of the width across the eyes. Ocelli colorless; eyes brown. Face yellowish brown, with brown arcs on the frons; rostrum dark brown. Frons large, rather swollen near the vertex; clypeus one and a half times as long as its breadth; loræ almost as wide as the clypeus. Pronotum grayish brown, with indistinct brown marks behind the eyes, about two-thirds of the length of the vertex; anterior margin broadly rounded; lateral margins very short; scutellum with two faint black marks on the middle, about two-thirds of the length of the pronotum; sternum and metapleura whitish yellow. Elytra with fuscous marks on the middle of the claval area; small black spot at apex of claval suture; corium with brownish marks on the middle, the anteapical cells marked with brown, and the costal margin before the apical cell black; elytra not as long as the abdomen; venation reduced. Abdomen above brownish yellow, beneath yellowish with brown for the middle and base. Female genitalia: Last ventral segment one and a half times as long as the penultimate, the posterior margin deeply concave; middle of posterior margin brown; pygofers three times as long as the last ventral segment, widely separated on the middle and converging to the tip of the ovipositor, not as long as the ovipositor; the latter strong, brown with sides black. Legs dull yellowish with the spines brown.

Described from one female.

Habitat: Cape Town (Mally).

Athysanus nemesia sp. n. (Pl. VIII, Fig. 1).

Brachypterous form. Color yellowish, faded. Length, 3.5 mm. Breadth 1.25 mm.

Vertex light yellow, flat on disc, sloping at sides; width between the eyes a little longer than the length of the vertex, anterior margin angularly rounded; eyes grayish, large, prominent; frons much wider than the clypeus and about two and a half times as long, whitish in color and traversed by numerous yellowish brown arcs; clypeus rather long, twice as long as its breadth, angular at apex; loræ narrower than the clypeus. Point of insertion of the antennæ surrounded by a brownish marking. Pronotum more than twice as broad as long, and shorter than the vertex, yellowish in color, lighter on the anterior half, the posterior half distinctly transversely striated; anterior margin broadly rounded, the lateral margins short; scutellum equalling the pronotum in length. Sternum yellow, dorsal surface lighter. Elytra with the venation distinct, but reduced, much shorter than the abdomen.

Genitalia: Male—last ventral segment not quite as long as the penultimate; plates roundly triangular, a little more than twice as long as the last ventral segment, and longer than the pygofers. Legs a dirty white.

Described from one male.

Habitat: Cape Town (Mally).

Genus **Thamnotettix** Zett.

Body oblong or oval, widest in the middle. Pronotum strongly curved in front, the side margins short. Head usually short. Scutellum generally as long or not quite as long as the pronotum. Elytra longer than the abdomen and overlapping at the apex.

This genus is well represented in South Africa, Stal having described a number of forms from the region of the Cape.

Thamnotettix karrooensis sp. n. (Pl. VIII, Fig. 2).

General color brownish white. Length 3.5 mm. Breadth 1.25 mm.

Vertex white, with a dilute brown pattern, angularly rounded, the length equalling the width between the eyes, and about one-third of the distance across the eyes. Eyes large, dark brown, ocelli dark brown, surrounded by clear white spaces. Face dull brown, the frons two and a half times as long as the clypeus, and twice as long as its width between the antennæ; clypeus narrow, its sides almost parrallel, twice as long as its width next the frons; loræ about equalling the clypeus in width. Pronotum well rounded on its anterior margin, dirty brown in color, with an irregular pattern, one and a third times as long as the vertex; sternum yellow; black spots on the pro-, meso- and metapleura. Scutellum almost as long as the pronotum, with brown markings on the middle and at the basal angles. Elytra a dull white, the veins distinctly marked with fuscous, the outer margin of the corium white, except for the minute brown spots. Abdomen dorsally black, with yellow margins, ventrally dirty white, with black on the base and the middle. Genitalia: Female—Last ventral segment two and a half times as long as the preceding, the posterior margin inwardly rounded and slightly produced on the middle; pygofer one and a half times as long as the width at base, and three times as long as the last ventral segment; ovipositor a little longer than the pygofers. Male: Valve brown, with a yellow border, last ventral segment equalling the penultimate in length, but not quite as long as the valve; plates long and narrow.

Described from numerous examples of males and females from Beaufort West, C. P. (Mally).

Thamnotettix karrooensis var. pallidus.

Form and shape the same as T. karroensis. General color light yellowish to whitish, with the brown coloration generally absent. Face light yellow, the frons marked with dilute brown ares. Ocelli san-

guineous. Genitalia female: last ventral segment almost two and a half times as long as the penultimate, white with brownish markings on the anterior half. Male: last ventral segment a little longer than the preceding. Males distinctly brown on the middle of the ventral part of the abdomen, the lateral margins yellow.

This variety was described from nine females and three males which were separated from T. karrooensis, on account of the absence of brown color pattern, and the general predominance of yellow.

Habitat: Beaufort West, C. P. (Mally).

Thamnotettix cotula sp. n. (Pl. VIII, Fig. 3).

General color yellowish brown. Length 3.5 mm. Breadth 1.25 mm.

Female: Head with the eyes prominent, vertex almost as long as the pronotum, fuscous yellow in color and characteristically marked with ten brown to black spots—two situated on the middle, one on either side of the median line, two somewhat smaller alongside these, but nearer the eyes, two large angular spots near the anterior margin, located close to one another and to the median line, two smaller spots on the anterior margin in advance of these; the other two spots are on the anterior half close to the lateral margin. The arrangement of these spots gives the insect a very characteristic appearance. Vertex acutely angled. Face strong, the frons fuscous with light arcs; clypeus almost twice as long as its width, less than half as long as the frons. Eyes large, dark steel gray; ocelli colorless located very close to the eyes. Pronotum fuscous yellow, equalling or a little longer than the vertex. Scutellum shorter than the pronotum, of the same yellow brown color. Elytra yellowish, transparent, the claval area irregularly marked with fuscous; apical cells fuscous at their borders. Abdomen above black, with yellow borders, beneath yellow. Legs light yellowish with alternate bands of fuscous on the coxæ and femora. Genital apparatus: ultimate ventral segment somewhat narrow, a little longer than the previous one, posterior margin notched at the middle, and rounding slightly to the sides; pygofers dark colored, twice as long as their width at base; spines strong and stout forming a rough crown at the tip of the ovipositor; the latter is longer than the pygofer, and is black at the sides and tip.

Male: General color the same as for the female; vertex shorter; the fuscous markings on the apical cells absent or not as prominent. Abdomen beneath dark brown. Genitalia: last ventral segment yellow on the middle, black at the sides, equalling the penultimate in length; valve semi-circular, small, not well exposed; plates angular at the tips, one and a half times as long as the last ventral segment; pygofers longer than the plates, rounded laterally; spines large.

Described from one male and one female.

Habitat: Cape Town (Mally).

Thamnotettix pentzia sp. n. (Pl. IX, Fig. 1).

General color brownish, somewhat smoky. Length of female 4.5 mm; male 4 mm. Breadth 1.35 mm.

Vertex about half the length of the pronotum; disk flat and sloping, width between the eyes greater than the length on the middle, color whitish marked irregularly with fuscous. Eyes large, dull reddish, extending back almost to the middle of the lateral margin of the pronotum; ocelli red, located near the eyes. Color of face, a dirty white with indistinct brown ares on the frons, the lorae brownish next the clypeus; width of frons at the eyes shorter than the length; clypeus a third of the length of the frons, rectangular in shape, its length being twice that of its breadth; lorae as wide as the clypeus. Antennae long, inserted deeply, the point of insertion being brownish. Pronotum twice as wide as its length, color bluish white with many transverse markings of a brown color and a distinct pattern; lateral margins yellowish, below black. Scutellum not quite as long as the pronotum, wider than long; with two prominently brown spots alongside the middle, and two yellowish markings at the basal angles, otherwise dirty white. Elytra white with the brownish pattern, very long, the appendix narrow, the margins transparent and without brown markings on the corium as far as the apical cells. Abdomen above black, whitish on the lateral margins, and black beneath. Genitalia female: last ventral segment almost three times as long as the penultimate, and about one and a half times as wide as its length, roundedly produced and notched on the middle; penultimate segment slightly curved inward on the middle of its posterior margin; pygofers two and a half times as long as the last ventral segment, and one and two-thirds longer than the width at base; ovipositor broad, light colored, except at the tip which is black, longer than the pygofer. Male: Whitish in color, the last ventral segment a little longer than the penultimate, valve small about one-third as long as the last ventral segment; plates sharp and long, about two and a half times the length of the ultimate ventral segment.

The males of this species are much lighter in color ventrally than the females.

Described from two females and one male.

Thamnotettix struthiola sp. n. (Pl. IX, Fig. 2).

General color bluish white with a brownish black pattern. Length 3.75 mm. Breadth 1.25 mm.

Vertex white with delicate though distinct black markings; a short median line extending from the posterior margin to the middle; width between the eyes about equal to twice the length of the vertex, which is flat on the disk, angularly rounded at the apex, and has its sides sloping; width across the eyes almost three times the length of the vertex. Eyes large, well rounded, dark gray in color; ocelli dilute red, located near the extremities of the frontal sutures. Face white interspersed with brown and black markings, which are somewhat variable in the different

individuals; frons with two brown markings near the margin of the vertex and from four to six brownish arcs on the middle, length five times as much as the width next the clypeus and two and a half times as long as the latter, which is strong, well rounded at the tip, where it is a little wider than at the base; clypeus about twice as long as its width; lorae not quite as wide as the clypeus, genae white, broad. Brown spots on the face between the frontal sutures and the eyes, just beneath the insertion of the antennae. Pronotum irregularly marked transversely with wavy brown; almost twice as long as the vertex, flat on the middle but slightly convex at the sides; lateral margins short; width of pronotum equal to twice its length; sternum jet black. Scutellum dirty brown with two blackish markings at the basal angles, a rectangular brown marking on the middle and extending to the apex; indistinct brown spots on the middle and anterior half; length about equaling that of the pronotum. Elytra whitish blue, with a distinct brown pattern; clavaI area rather long, leaving a small apical area; outer borders white or with few brown marks. Genitalia male: Last ventral segment brownish, a little longer than the penultimate; valve almost as long as the ultimate segment, plates long, slender and sharp, much longer than the pygofers and about three times as long as the last ventral segment; tips very pointed. Female: Last ventral segment whitish, about four times as long as the preceding; posterior margin inwardly and angularly rounded, then produced on the middle, the production being pronounced; slightly convex on the top; pygofers brownish, strong, almost three times as long as the last ventral segment and more than twice as long as their width at base; rather widely separated; ovipositor long and broad, longer than the pygofers, sharp at the tip.

Described from three females and four males.

Habitat: Beaufort West, C. P. (Mally).

Tribe Cicadulini.

Genus **Cicadula** Zett.

Body elongate or oblong, usually much narrowed behind. Head obtuse in front; frons almost straight sided. Pronotum usually longer than the vertex. Elytra longer than the abdomen, overlapping at the apex; appendix present; inner sector not forked.

Cicadula 6-notata Fall.

Cicadula sexnotata Fallen. Acta Holm. XXII. 34. (1806).
Edwards. Hem. Homop. Brit. 1s. 187. (1896).
Melichar, Cicad. v. Mittel-Europa. 309. (1896).
Osborn. Bull. U. S. Dept. Agr. No. 108. 97. (1912).

General color light yellowish green. Length 3.5 to 4 mm.

Vertex marked characteristically with six black spots arranged in pairs, two on the anterior margin near the middle, two larger posterior to these, and two smaller spots on the hind part of the vertex. Frons prominently marked with black lines. Body black above, yellow below; abdomen black with the lateral ventral borders yellow. Genitalia:

Last ventral segment of female yellow, a little longer than the penultimate; pygofer yellow, ovipositor black, equalling the pygofer in length. Male: Color whitish, valve short, somewhat angular; pygofer longer than the plates, which are triangular.

This insect is here recorded from South Africa for the first time. It is widely distributed over Europe and North America, having attracted considerable attention on those two continents because of its economic importance. Osborn places it among the six most important leafhoppers affecting cereal and forage crops in the United States. Its occurrence in South Africa is interesting, in view of the attention which it has attracted in other countries.

Habitat: Cape Town (Mally).

Cicadula longiforma sp. n. (Pl. XI, Fig. 3).

Form long and slender, resembling a Gnathodus to some extent. General color light yellow. Length of female 4.25 to 4.5 mm.; male 4 mm. Breadth 1 mm.

Vertex yellow, narrow, rounded anteriorly; two light brownish arcs on the anterior margin, a small longitudinal line on the middle, extending from the posterior margin; length about one-third of the width between the eyes. Face generally yellowish brown, with the cheeks lighter in color; frons twice as long as its width, and three times the length of the clypeus, with six arcs traversing its surface; cheeks rather broad, equalling the frons in width; clypeus about one and a half times as long as its width and about as wide as the lora. Eyes large and prominent, black below and grayish above; ocelli dilute brown, located close to the eyes. Thorax well developed, the pronotum three times as long as the vertex; slightly convex on the middle; color light yellow with many irregular and indistinct brown markings on the anterior half; anterior margin well rounded between the eyes, the posterior straight. Scutellum yellowish, with a few irregular faint brown spots, basal angles of a deeper hue than the apex, more than half as long as the pronotum, with a distinct transverse line on the middle. Elytra long, much longer than the abdomen, faint yellow, transparent; length exceeding the abdomen by the distance from the apex of the claval suture to the apex of the membrane. Abdomen above brownish, yellow at the lateral margins; beneath yellow, interspersed with black. Legs light yellow with the tarsi brown. Genitalia: Female—last ventral segment longer than the penultimate, emarginate, convex; pygofers long and narrow, widely separated at the base, about twice as long as the last ventral segment and about one and a half times as long as the width at base; ovipositor equalling the pygofers in length, rounded at the tip. Male: Last ventral segment large, longer than the preceding; valve thick, shorter than the last ventral segment; plates long and narrow at the tips; pygofers longer than the plates.

Described from two males and two females.

Habitat: Cape Town, C. P. (Mally).

FAMILY TYPHLOCYBIDÆ.

The members of this family may be easily recognized by the four longitudinal veins or sectors of the elytra, which fork at the base and run to the cross-nervures, forming the apical cells. There are no anteapical cells in the elytra, nor is there a supernumerary cell present in the hind wings.

Genus **Empoasca** Walsh.

Generally small species, with the sectors of the posterior wings ending in a marginal vein, and with one apical cell in the hind wing. No appendix present on the elytron.

Empoasca protea sp. n. (Pl. X, Fig. 1).

Color greenish yellow, with the green predominating. Length 2 mm. Breadth .5 mm.

Face light yellow, fainter next the clypeus; genæ, loræ and clypeus light green. Entire length of face exceeding the breadth by about one-half of the former. Head somewhat large, slightly wider than the pronotum; vertex greenish, with irregular dark markings, and a faint white line extending along the middle from the posterior to the anterior margin; slightly elevated, giving a convex appearance. Anterior of head angularly rounded, the angle less than a right angle. Eyes dark green to black, large; width between eyes a little more than the length of the vertex. Pronotum brownish green, with a faint white line on the middle, running longitudinally from the posterior margin almost to the anterior edge; two rather indistinct spots on either side of this line, located on the anterior half; length of pronotum a little greater than the vertex; anterior margin almost straight between the eyes, lateral margins rounded, slightly convex above; twice as wide as its length. Scutellum greenish brown, about equalling the pronotum in length; a small transverse furrow near the apex. Elytra light green, translucent; venation distinct. Hind wings with the marginal vein somewhat produced. Abdomen yellowish, below greenish. Legs green, yellow at coxæ. Female genitalia: distinct green, last ventral segment twice as long as the penultimate, sinuate and roundedly produced on middle. Pygofers strong, twice as long as the width at base, ovipositor a little longer.

Described from three females.

Habitat: Table Mountain, Cape Town (Mally).

Empoasca heliophila sp. n. (Pl. X, Fig. 2).

Color yellowish, more or less tinged with green. Form long and slender. Length 3 mm. Breadth scarcely 1 mm.

Face distinctly yellow, shading into greenish below, long and slender, with the clypeus about one-third of the length of the frons. Cheeks and loræ greenish yellow; eyes pale green. Ocelli present, located on the anterior margin of the head, brown in color. Vertex yellow, slightly produced in front, its length less than the breadth between the eyes, and

equal to about half the length of the pronotum and about one-third of the total width of the head across the eyes. Pronotum yellow, lighter than the head on its posterior half; not quite as long as the width between eyes. Scutellum light brown to yellow, not quite as long as the pronotum. Elytra pale greenish yellow. Abdomen dorsally yellowish green, venter greenish. Legs light yellowish green. Female genitalia: Last ventral segment more than twice as long as the penultimate, produced on middle, rounding to the sides; pygofers twice as long as their width at base. Ovipositor longer than the pygofers.

Described from three females.

Habitat: Cape Town (Mally).

Genus **Typhlocyba** Germ.

Sectors of the posterior wings ending in the wing margin, no marginal vein. Only three veins running to the margin.

Typhlocyba purpureatincta sp. n. (Pl. X, Fig. 3).

Color dark brown above, tinged with purple, beneath yellowish. Length almost 3.25 mm. Breadth 1 mm.

Face brownish yellow, the clypeus darker, almost black, with the cheeks and lorae light yellow. Eyes black above, yellow below. Vertex faint yellow, with two irregular dark spots near the middle, moderately produced, the apex considerably rounded; anterior margin angularly rounded, the angle less than a right angle; length of vertex about equal to half the width between the eyes. Pronotum brown above, yellow beneath, anterior margin well rounded between the eyes; posterior half wider than the head; almost twice as broad as its length and about twice as long as the vertex; posterior margin slightly concave; two furrows running from the middle behind the eyes, to a little beyond the posterior half. Scutellum brownish at angles next the pronotum, with a rectangular purplish marking on the middle; indistinctly striate; a little longer than the pronotum. Elytra light brown, with a distinct purple tinge, translucent, the veins showing as darker brown lines; a pronounced longitudinal purple marking on the outer margin of the middle of the corium; entire margin of elytron of a darker hue than the remainder; two apical cells apparent in posterior wing. Abdomen yellowish brown dorsally, dirty yellow ventrally. Legs a dirty yellow, hind tibiae hinged with purple. Female genitalia: dark purple, the last ventral segment brownish, a little longer than the penultimate; ovipositor narrow, a little longer than the pygofers.

Described from two females.

Habitat: Table Mountain, Cape Town (Mally).

Typhlocyba mallyi sp. n. (Pl. XI, Fig. 1).

General color yellowish brown, with the elytra dull greenish. Form short and stout. Length not quite 3 mm. Breadth a little more than 1 mm.

Vertex yellowish brown, unicolorous with the face, not produced at all; considerably rounded anteriorly, and slightly elevated at the middle;

about half as long as the pronotum; a small black line extending from the posterior margin to the middle; width between the eyes about three times the length of vertex. Face yellowish brown with the frontal sutures almost black; frons narrow, three times as long as its width; clypeus dark brown, about one-fourth of the length of the frons; loræ small, light yellow; cheeks somewhat fainter in color. Ocelli present, colorless, located at the extremities of the frontal sutures. Pronotum yellow on anterior half, brown on posterior. More than twice as broad as long, the length being less than the width between the eyes; side margins rounded, posterior margin slightly concave on middle; somewhat rugose, and concave on top. Scutellum yellow, with two brown spots at the base, and an indistinct spot near the apex; slightly longer than the pronotum. Elytra greenish brown with traces of yellow on the claval area; transparent; margin of the clavus light brown, the corium greenish, with a longitudinal brown marking on the middle, extending from the margin to the second sector. Abdomen above black, brownish at the tip, and yellowish brown beneath. Female genitalia: Last ventral segment strongly produced to a blunt point, brown on middle with yellow borders, twice as long as the penultimate segment; pygofers stout, a little longer than their width at base; ovipositor a little longer than the pygofers. Legs light yellow, becoming brown at the tarsi.

Described from one female.

Habitat: Cape Town (Mally).

Typhlocyba elegia sp. n. (Pl. XI, Fig. 2).

Form long, sharp; color light yellow, the vertex and pronotum marked with brown. Length 4 mm. Breadth 1.5 mm.

Face pale yellow, greatly elongated, almost twice as long as its breadth; frons narrow, the sutures almost parallel, about four times as long as the clypeus, which is short, and a little longer than wide. Cheeks and loræ white, the latter long and narrow; clypeus black. Eyes black with a whitish band on the middle. Vertex yellow, somewhat produced, the anterior end rounded, not as long as the pronotum, and shorter than the width between the eyes; a large brown irregular spot on the middle of the disc. Pronotum pale yellow, with a large brown marking on the middle, extending from anterior to posterior margin and widening considerably on the middle; indistinct brown marks on the lateral margins. Scutellum yellow with two black spots at the basal angles, and a large black spot at the apex; brownish markings on the middle; not as long as the pronotum. Elytra yellow, transparent, with brown markings on the claval area, also on the corium, parallel to the claval suture; much longer than the abdomen; middle apical cell narrow, the sides subparallel. Abdomen above brown, white on the borders and bright yellow beneath. Female genitalia: Last ventral segment twice as long as the penultimate, strongly produced, the production being V-shaped; pygofers strongly rounded to the sides, ovipositor strong, a little longer than the pygofers, black at the tips. Legs light yellow.

Described from three females.

Habitat: Cape Town, C. P. (Mally).

Date of Publication, March 17, 1916.

EXPLANATION OF PLATES.

PLATE IV.

Figure 1. Macropsis subolivaceus Stal. a, adult; b, face; c, male genitalia; d, female genitalia; e, elytron.
Figure 2. Pediopsis capensis. a, adult; b, face; c, male genitalia; d, elytron.
Figure 3. Idiocerus hewitti. a, adult; b, elytron; c, female genitalia.

PLATE V.

Figure 1. Agallia nigrasterna. 1, adult; 2, face; 3, elytron; 4, male genitalia; 5, male genitalia, side view.
Figure 2. Agallia cuneata. 1, adult; 2, face; 3, female genitalia; 4, elytron.

PLATE VI.

Figure 1. Cephalelus infumatus Perch. 1, adult female; 2, adult male; 3, nymph; 4, face; 5, female genitalia; 6, male genitalia; 7, dorsal view of posterior end of female abdomen.
Figure 2. Deltocephalus breviatus. 1, adult; 2, face; 3, female genitalia; 4, male genitalia; 5, elytron.
Figure 3. Deltocephalus aristida. a, adult; b, face; c, female genitalia; d, elytron.

PLATE VII.

Figure 1. Athysanus capicola Stal. a, adult; b, female genitalia; c, male genitalia; d, face; e, elytron.
Figure 2. Athysanus aethiopica. a, adult; b, female genitalia; c, face; d, male genitalia; e, elytron.
Figure 3. Athysanus eriocephalus. a, adult; b, female genitalia; c, male genitalia; d, face; e, elytron.
Figure 4. Athysanus cyclopia. a, adult; b, female genitalia; c, face; d, elytron.

PLATE VIII.

Figure 1. Athysanus nemesia. 1, adult; 2, face; 3, male genitalia; 4, elytron.
Figure 2. Thamnotettix karooensis. a, adult; b, female genitalia; c, male genitalia; d, face; e, elytron.
Figure 3. Thamnotettix. cotula. a, adult; b, female genitalia; c, male genitalia; d, face; e, elytron.

PLATE IX.

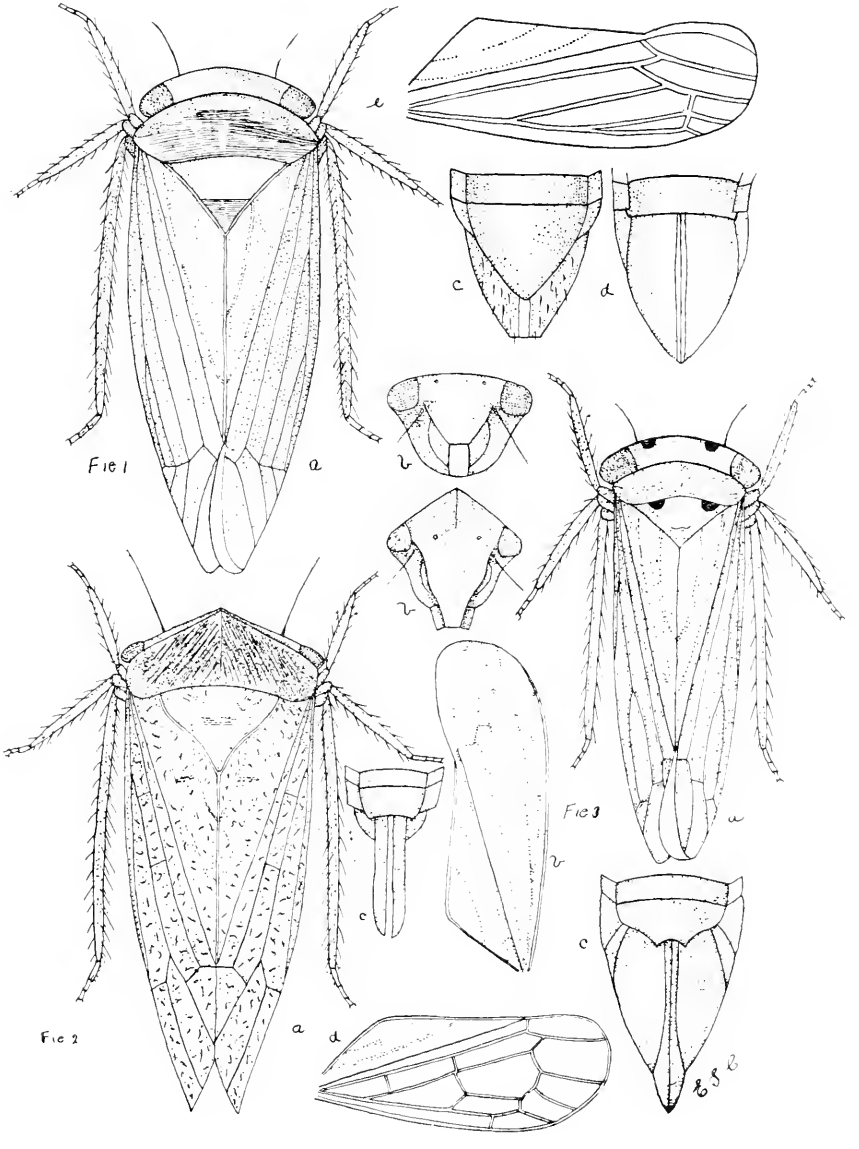
Figure 1. Thamnotettix pentzia. 1, adult; 2, face; 3, male genitalia; 4, female genitalia; 5, elytron.
Figure 2. Thamnotettix struthiola. 1, adult; 2, face; 3, female genitalia; 4, male genitalia; 5, elytron.

PLATE X.

Figure 1. Empoasca protea. a, adult; b, female genitalia; c, face; d, elytron; e, hind wing.
Figure 2. Empoasca heliophila. a, adult; b, face; c, female genitalia; d, elytron; e, hind wing.
Figure 3. Typhlocyba purpureatineta. a, adult; b, face; c, elytron; d, hind wing.

PLATE XI.

Figure 1. Typhlocyba mallyi. a, adult; b, female genitalia; c, face; d, elytron; e, hind wing.
Figure 2. Typhlocyba elegia. a, adult; b, face; c, female genitalia; d, elytron; e, hind wing.
Figure 3. Cicadula longiforma. a, adult; b, face; c, female genitalia; d, male genitalia; e, elytron.



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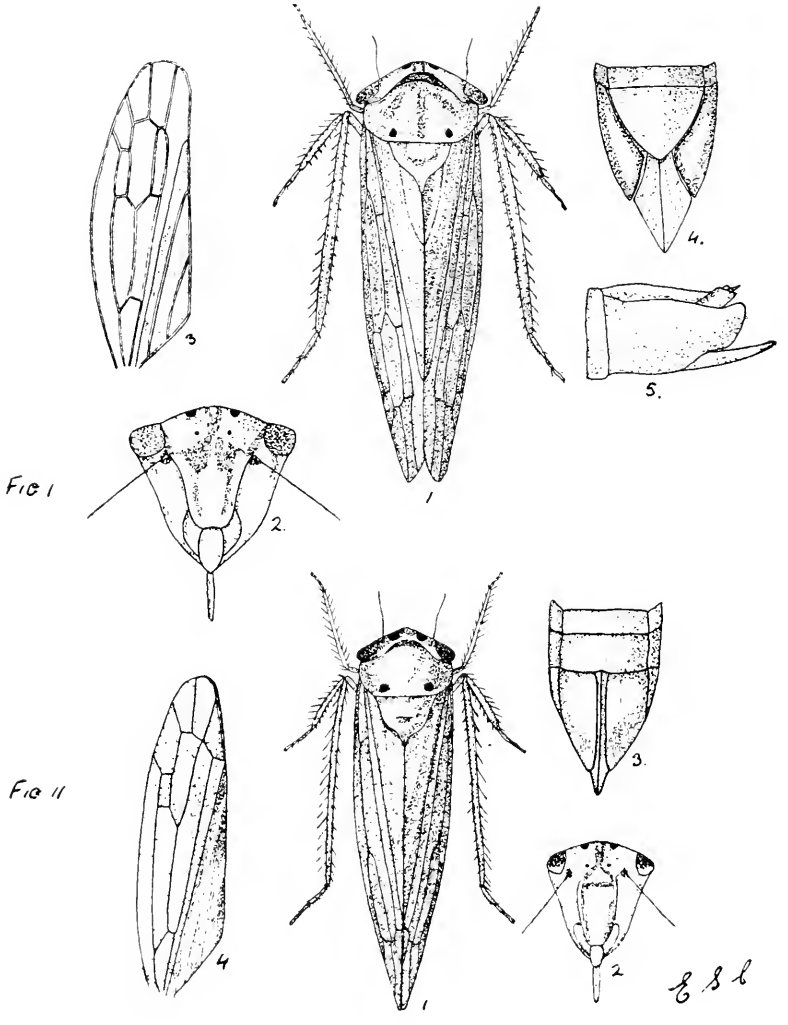

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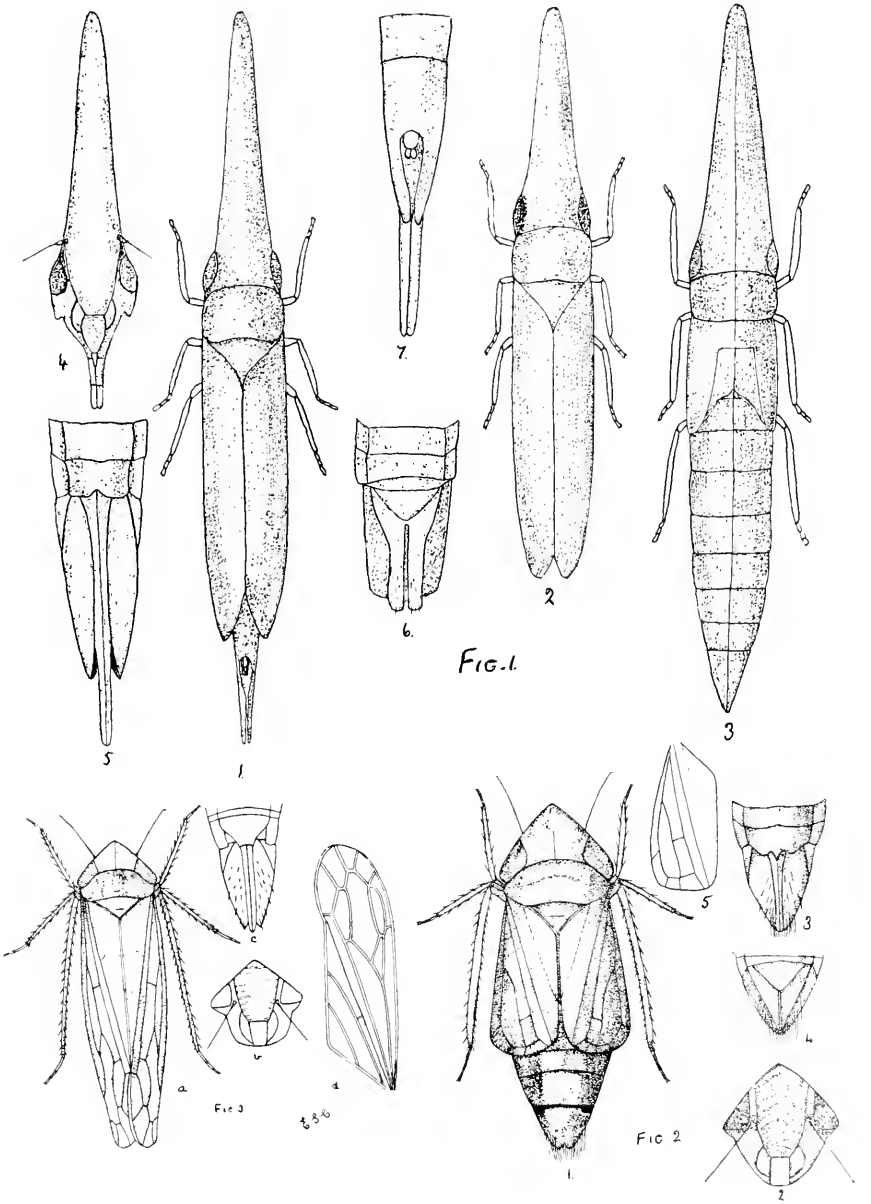

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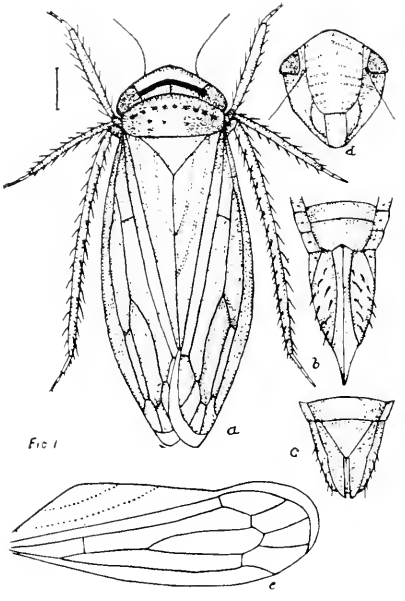


FIG 1

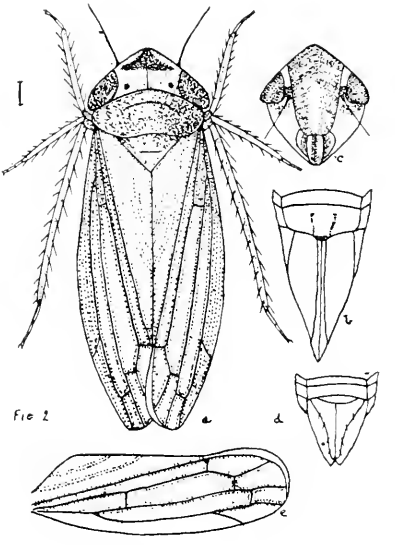
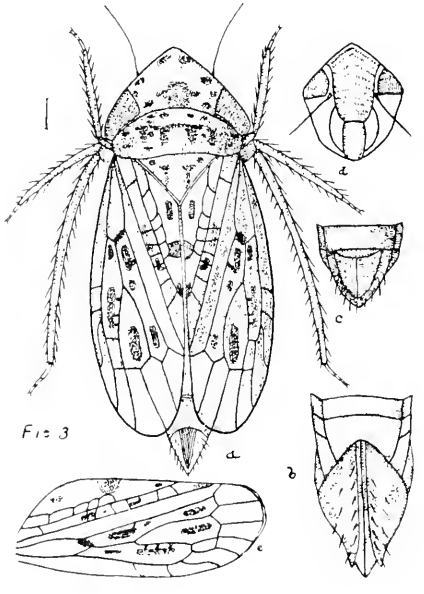


FIG 2



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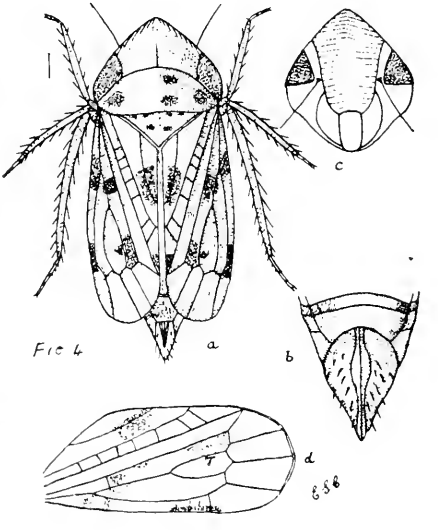

FIG 4

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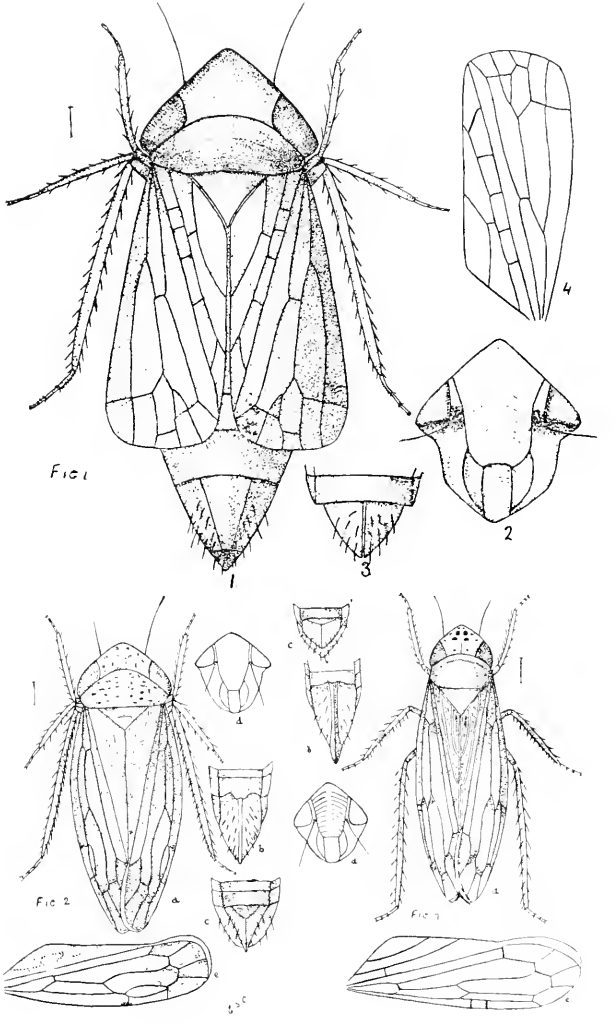

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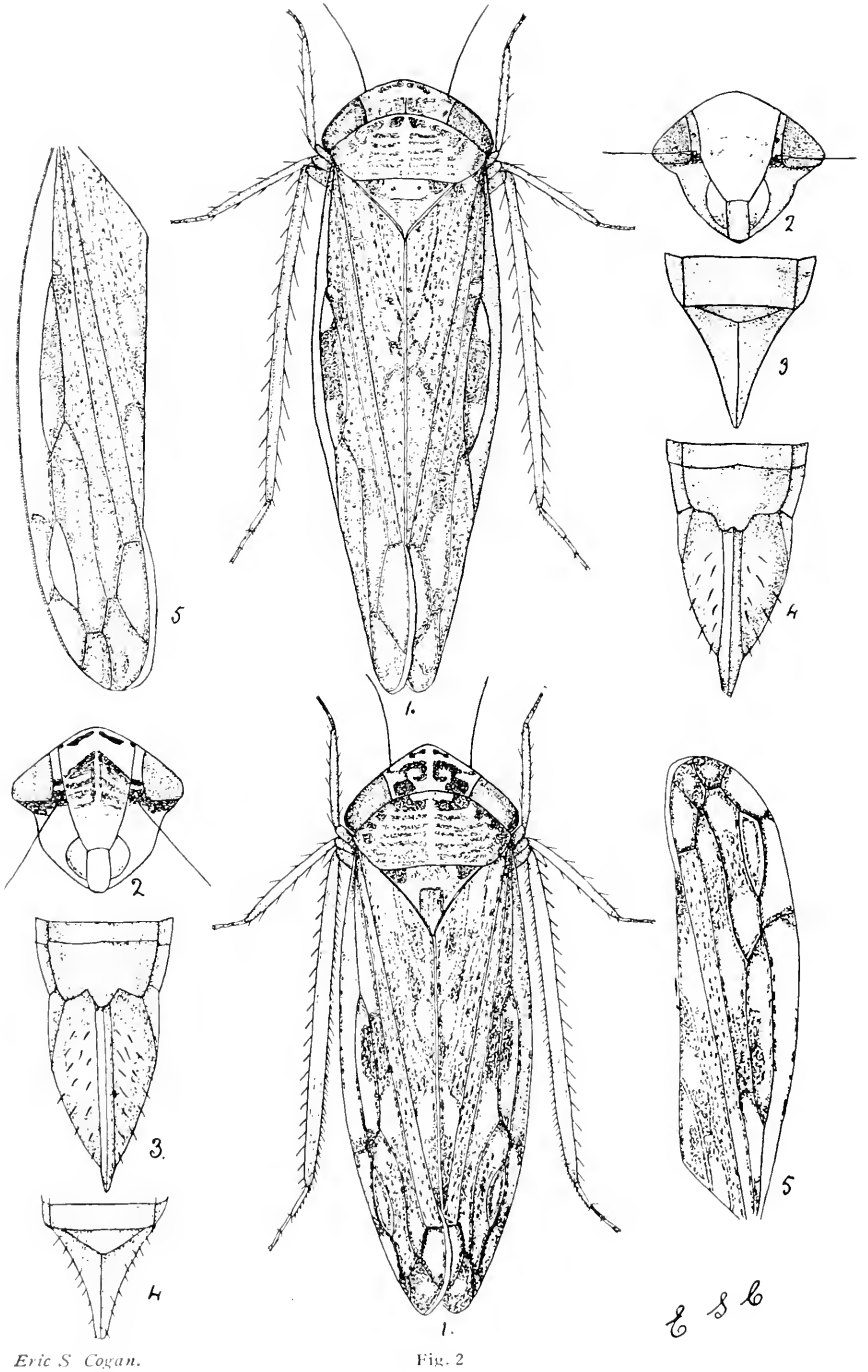


Eric S Cogan. Fig. 2

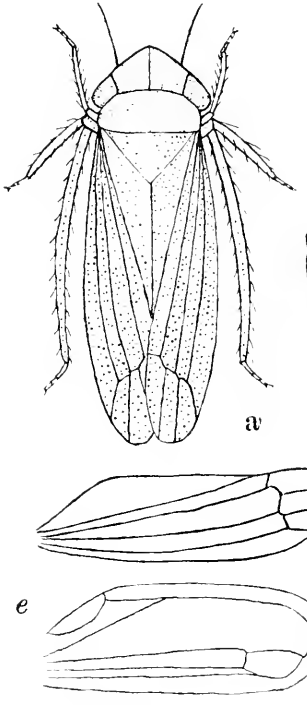


Fig. 1

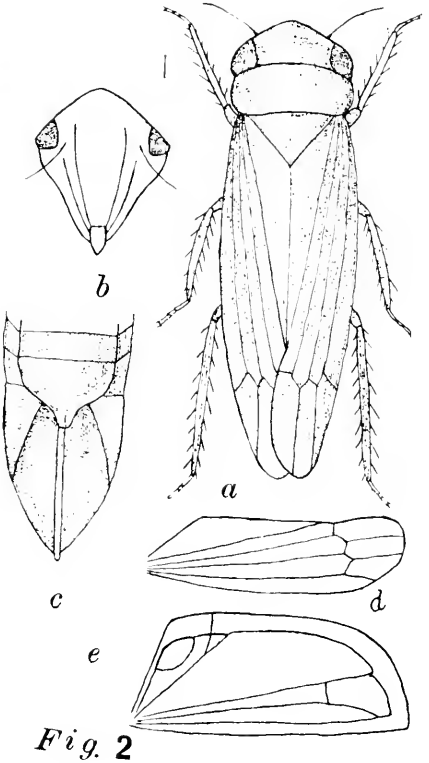


Fig. 2

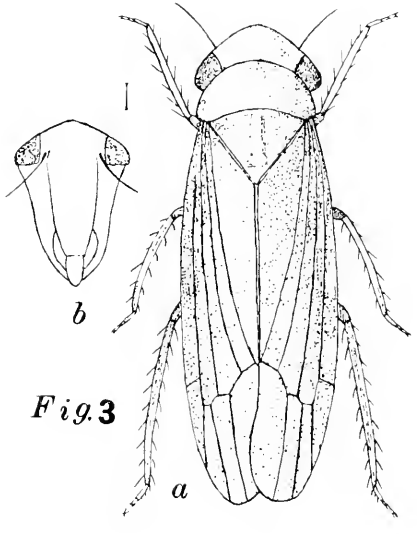
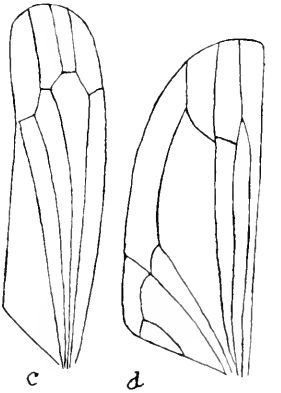


Fig. 3



E.S.C.

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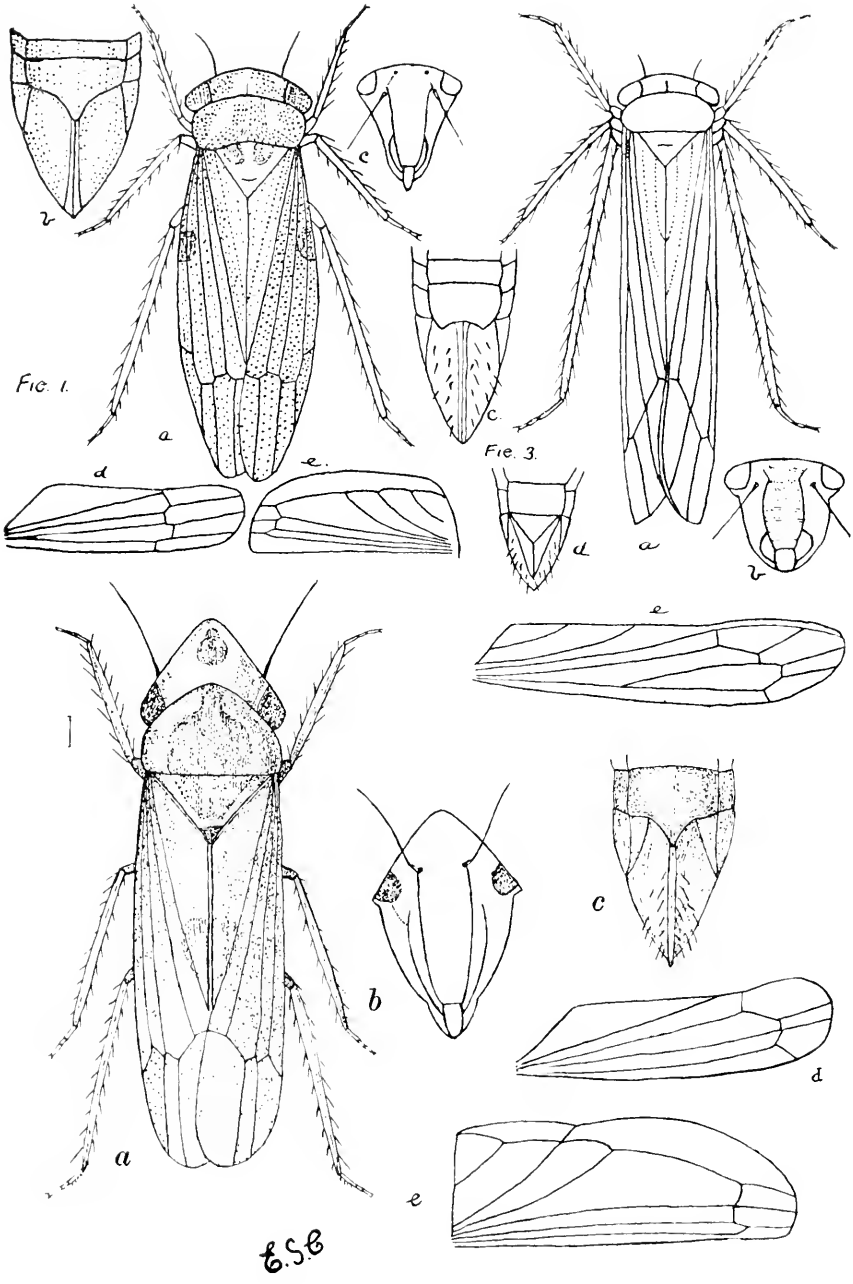

Fig. 2

Eric S. Cogan

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REAMES CAVE.

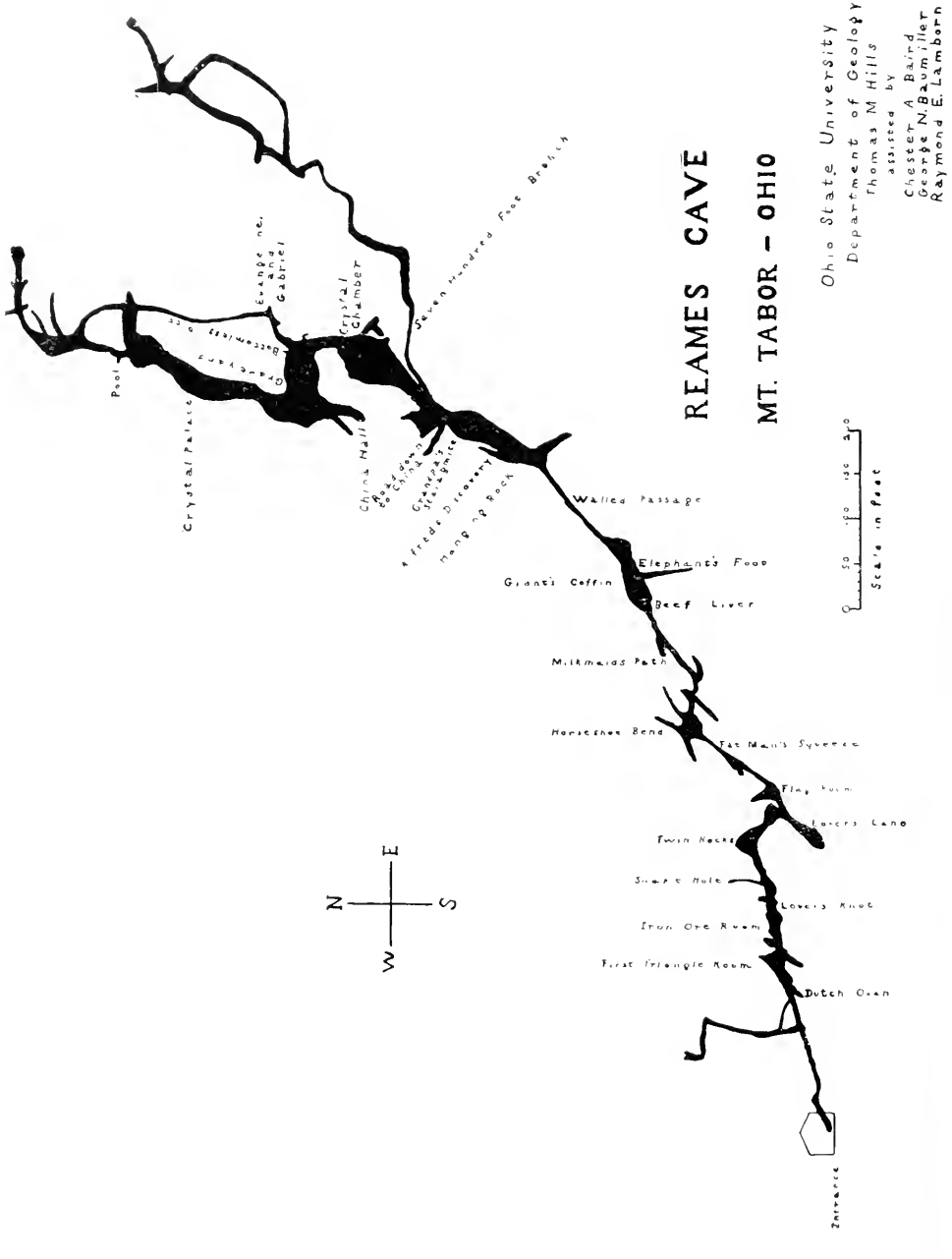
THOMAS M. HILLS.

Reames Cave is also called Mount Tabor Cave, because of its location in Mount Tabor. It is on the Reames farm and owned by the Reames family, who wish it called by their name. For these reasons the title name was adopted.

The Cave lies along the northern border of Champaign county, in the west central part of Ohio. It can be reached most easily, by way of the Big Four Railroad or the Ohio Electric Railway, from West Liberty, a small town four and a half miles to the northwest.

Mount Tabor is an elevation 1278 feet above sea level along the eastern side of the Mad River valley. It lies between that river and the prominent moraine of the Late Wisconsin ice sheet that forms the eastern side of the valley from Bellefontaine southward.

The Cave is located at the northern end of a ridge which is partly limestone and partly glacial drift. This ridge is a mile and a half long, a half mile wide and eighty feet above the stream beds to the east and west of it. It is of topographic importance because somewhat isolated from the high morainal ridge to the east which would otherwise overshadow it. This isolation is partly due to the present drainage of the region and partly to preglacial erosion.


REAMES CAVE
MT. TABOR – OHIO
Ohio State University
Department of Geology
Thomas M Hills
assisted by
Chester A Baird
George N. Baumiller
Raymond E. Lamborn
Crystal Palace
Pool
Crystal Chamber
Seven Hundred Foot Branch
China Hall
Walled Passage
Elephant's Foot
Giant's Coffin
Beef Liver
Milkmaids Path
Horseshoe Bend
Twin Necks
Lovers Knot
Iron Ore Room
First Triangle Room
Dutch Oven
Entrance
N
S
E
W
Scale in Feet

The drainage is into the Mad River valley and is mostly surface run-off except in the vicinity of Mount Tabor, near both ends of which and to the southward are depressions. There is no doubt that some of these are sinks. Some, however, may be kettle holes associated with the near presence of the broad moraine. The abrupt ending of some small streams in ponds near Mount Tabor, shows that there is underground drainage in its immediate vicinity.

Geologically, the cave is located in the Columbus limestone, a small outlier of which forms Mount Tabor. This is a small edition of a similar situation in the double pointed hill near Bellefontaine.

Several small quarries have been opened near the base of the Mount, for local use. In a specimen from one of these Miss Rose Gormley identified the following fauna: Atrypa reticularis, Atrypa spinosa (?), Cyrtina hamiltonensis, Leptæna rhomboidalis, Rhipidomella vanuxemi, Spirifer divaricatus (?), Stropheodonta hemispherica, Zaphrentis cornicula (?), Dalmanites calypso.

This fauna, together with the lithologic character of the limestone, and the fact that at the cave entrance is exposed fifteen feet of Ohio shale immediately above the limestone, leaves no doubt as to its age. The Ohio shale at the entrance is the only known occurrence of it on the hill. It seems to have been protected from ice erosion, because it occupied the bottom of a shallow sink, which subsequently enlarged and deepened to form the present cave entrance.

Glacial drift covers the southern end of Mount Tabor in a train that stretches out from the limestone core. The northern end of this core was left exposed by the ice. It has the steep slope to the north and the drift to the lee characteristic of ice shaped hills.

Reames Cave is approximately 1800 feet long. Its general form is that of the letter *Y*, the entrance being at the base of the letter and the fork 1100 feet from it. The passages run in a northeast direction up to the fork, where one continues along the same line and the other branches off to the north. (See map).

The width of the accessible galleries varies considerably. The maximum is fifty feet. Where this wide the height of all but a small passage may be reduced from a maximum of twenty-five feet to three feet or less. The wider places are

usually at the intersection of two joint planes. This is not true of the northern arm. Its rooms are the largest in the cave and occur along a single joint plane.

Reames Cave is one of the largest if not the largest in Ohio. It owes its size to the extent of its narrow chambers, rather than to their width or height. These chambers are all on one level or nearly so. The floor at the entrance is thirty feet below the ground surface. It descends gradually to the northeastward, but so gradually that at the extreme end of the cave

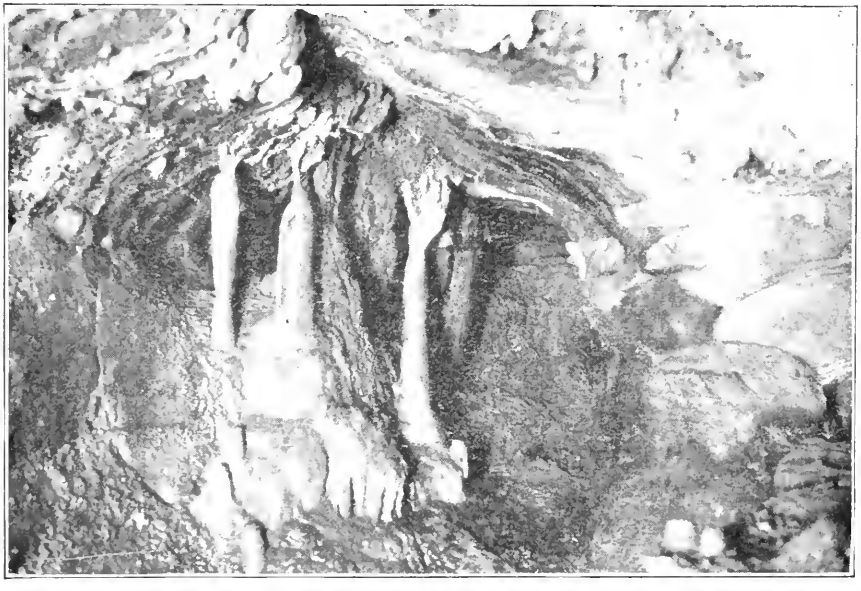


Figure 2. The Crystal Chamber with columns of iron oxide and calcium carbonate.

a descent sixty-five feet below the surface is unnoticed. Most of this descent is along the eastern arm of the Y.

At the extreme end of both branches the floor of the cave is quite muddy, due to the constant dripping from the roof, at least in part. This is due to the fact that the cave in its northeasterly course passes beyond the limit of the Mount Tabor hill and is partly under the valley to the east of it. While the surface drainage into this valley from Mount Tabor carries off most of the water, enough descends through the mantle rock to give an abundant supply for solution and deposition in the cave.

The rooms are small and narrow near the entrance, but increase in size toward the inner end. They follow a northeast-southwest joint plane which can be seen along the roof. Figure 2 shows one of these joint planes. The "Crystal Chamber" pictured is not the main gallery, but runs at right angles to it.

Solution has widened the joint plane along layers that are decidedly saccharoidal in texture. This expanded area is usually near the roof of the cave. The cross-section thus formed resembles a plus sign, the lower end of which is partly filled with residual fragments and sticky clay. At certain places solution along the bedding planes far surpasses that in the other directions and the larger rooms such as the Crystal Chamber (Fig. 2) and the Graveyard (Fig. 3) are produced.

The exact location of the cave among the zones of the Columbus limestone can not be stated with certainty, but it is thought to be near the base of the formation, probably in zones *B* and *C* of Stauffer.* The walls are coated at most places with deposits, but the abundance of corals in the roof, indicating zone *C*, and the saccharoidal layers below, which in the upper part contain many cherty nodules, with a general scarcity of fossils, and the massive character of the strata agree with the description of zone *B*.

The concretions in the saccharoidal layers stand out prominently along the upper part of the walls of the cave. They deserve special mention because of the suggestive names that have been given them, such as "Beef's Heart" and the "Ham." In size they vary from a few inches to several feet in diameter.

The deposits on the walls and roof are of two kinds, calcium carbonate and iron oxide. These have been and are being deposited contemporaneously. The walls are coated with alternating layers of them. At some places, as in the "Flag Room" these are arranged in vertical stripes, while at others the calcite is the present outside coating which gives the white color of the "Milky Way" and other similar passages.

One peculiarity of the iron deposits is the arrangement into a cell-like structure resembling a honeycomb, or better the leaf scars of a Lepidodenron. The calcite forms the comb and the iron oxide the honey of the first illustration. This can be seen imperfectly, to the right of the stalactites in the picture of the

*Geological Survey of Ohio, Bulletin 10, pp. 36–37.

Crystal Chamber, Figure 2. It occurs on the walls and roof of the cave at many places, resembling a structure of organic origin, though that does not seem possible. No explanation is offered. In Figure 2 stalactites of iron oxide, the darker

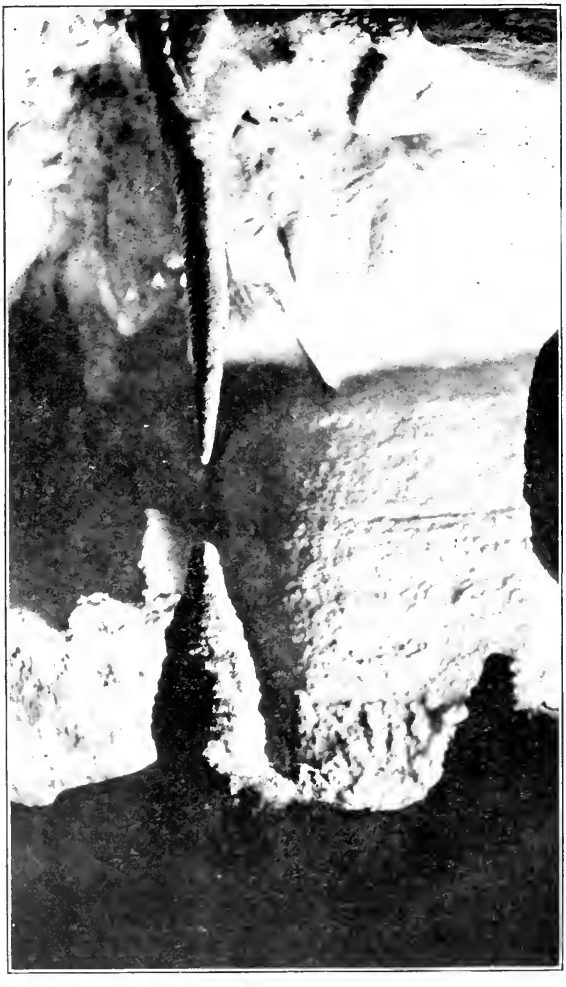


Figure 3. "Evangeline and Gabriel."

columns in the inner part of the recess, and calcite, the lighter columns, shows the close association of these two minerals. The change in the diameter near the middle of the column at the left in the same illustration, is characteristic of many

of them, especially the larger ones. It occurs in those composed of both minerals and those of only one. A constriction should occur where stalactite and stalagmite meet. Most of the large stalactites show two however. The question might be raised whether an increased water supply would cause more rapid deposition. This might be brought about by glaciation or a number of other ways. Figure 3 of the stalactite and stalagmite "Evangeline and Gabriel," two of the largest columns in the cave are without any suggestion of constriction. They are not, however, in the main cave, but off at the extreme end of a narrow side branch which is quite dry at present and may have been so for a long time.

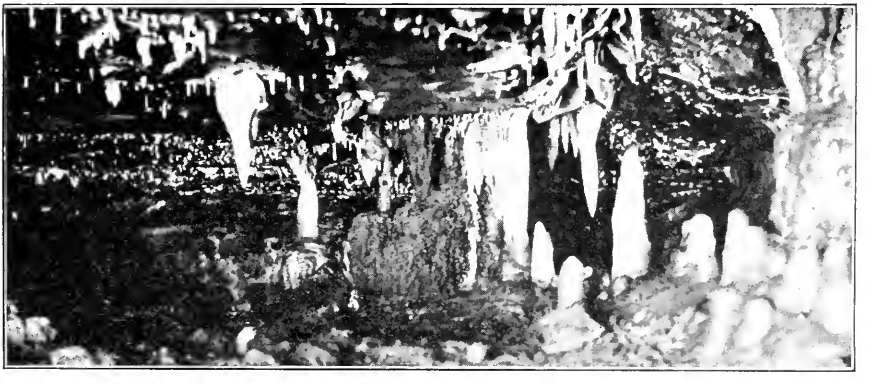


Figure 4. "The Graveyard."

The smaller stalactites are simple in form. Hundreds of them, about the size of a cigarette, are hollow thin walled tubes, that hang from the roof in the wider part of the cave. They are still covered and filled with water and probably started their growth at a not distant past. The larger ones are from three to five feet long. Figure 4 of the "Graveyard" is a good illustration of the abundance of the small ones.

The time when the cave began to be formed is unknown. The only evidence as to its age is derived from comparing it with other solution cavities in the Columbus limestone, known to be pre-glacial.* These are so much smaller that it seems probable the cave was in existence long before glaciation.

The cave had no surface opening until in August, 1897, when the ground sunk at the present entrance.

*Hubbard, Geological Survey of Ohio, Bulletin 14, p. 63.

THE TOLEDO CEDAR POINT.

E. L. Fullmer.

Several projections of land in Ohio are known locally as Cedar Point. The one here briefly described is in Lucas County on the south shore of Lake Erie and just east of the entrance to Maumee Bay. It is some ten miles from Toledo. Here a large tract of low and swampy land is known as Cedar Point. From the accompanying map based on the United States topographical map of the area an idea of the location and character of this region may be obtained.

It may be seen that there is a large tract of swampy land extending back from Lake Erie as much as two miles in places. A considerable part of this swamp lying to the south and east of, C, has been reclaimed. Dikes were built across the swamp and the excess water pumped out; large ditches or canals being used to drain the water to the pumping plant. Good crops of onions are now grown on this reclaimed land.

Just inland from the swamp is a low lying tract, H, of very level land; the surface of which lies but a few feet above the water level in the lake. Ward Canal, W, is a drainage channel cut through this region. When seen by the writer the surface of the non-flowing water in this canal was not more than four feet below the surface of the ground at a distance of three miles from the lake. Of course this level varies somewhat with changes in the lake level and no doubt the water in the canal rises in times of rainfall as some of the higher land still further inland is drained into it.

Extending all along the swamp on both the bay and the lake sides is a narrow low sandy beach. It is from fifty to two hundred and fifty feet wide and the highest parts are but little above the reach of waves of violent storms. This beach extends in an unbroken line except for one channel, O, opening into the swamp from the lake. This channel is a little over a mile from the extreme end of the land, B, and is a deep water course perhaps some three hundred feet wide where it enters the swamp. It extends back a considerable distance into the swamp and is no doubt kept open by the currents set up as the water flows into and out of the swamp with each change in the level of the lake.

In some of the wider parts of the beach a narrow sand plain has developed, on portions of which Cottonwood has gained a foothold and has formed a few small groves of half grown trees.

The writer had an opportunity to visit this region in the summer of 1915 and spent two days, Aug. 30 and Sept. 1, collecting botanical specimens upon the beach. The following list of plants collected will show the nature of the flora, although the list of herbs could be much extended. No Cedars or other Conifers are now growing in this region and I was unable to learn the reason for the name Cedar Point being applied to it.

Trees:

Acer rubrum L.—Three small trees only found.
Catalpa sp.—One specimen two feet tall.
Fraxinus pennsylvanica Marsh—A few small trees.
Populus deltoides Marsh—Abundant.
Platanus occidentalis L.—Three small trees.
Gleditsia triacanthos L.—One specimen.
Celtis occidentalis L.—One small specimen.
Salix amygdaloides Anders—Abundant.
Salix interior Rowlee—Abundant.

Shrubs:

Cornus amomum Mill.—Three clumps.
Rhus glabra L.
Rhus hirta (L) Ludw.
Ribes americanum Mill.—Infrequent.
Sambucus canadensis L.—Infrequent.

Woody Vines:

Parthenocissus quinquefolia (L) Planch. Common.
Vitis vulpina L.—Common.

Herbs:

Astragalus carolinianus L.
Asclepias syriaca L.
Apocynum sibiricum Jacq.
Ambrosia trifida L.
Cakile edentula (Bigle) Hook.
Cenchrus tribuloides L.
Clematis virginiana L.
Chamaesyce polygonifolia (L) Small.
Falcata comosa (L) Kuntze.
Heliopsis scabra Dunal.
Melilotus alba Desv.
Oenothera biennis L.
Physalis sp.
Solidago serotina Ait.
Spartina michauxiana Hitch.
Solanum dulcamaria L.
Tinaria scandens (L) Small.
Verbascum thapsus L.

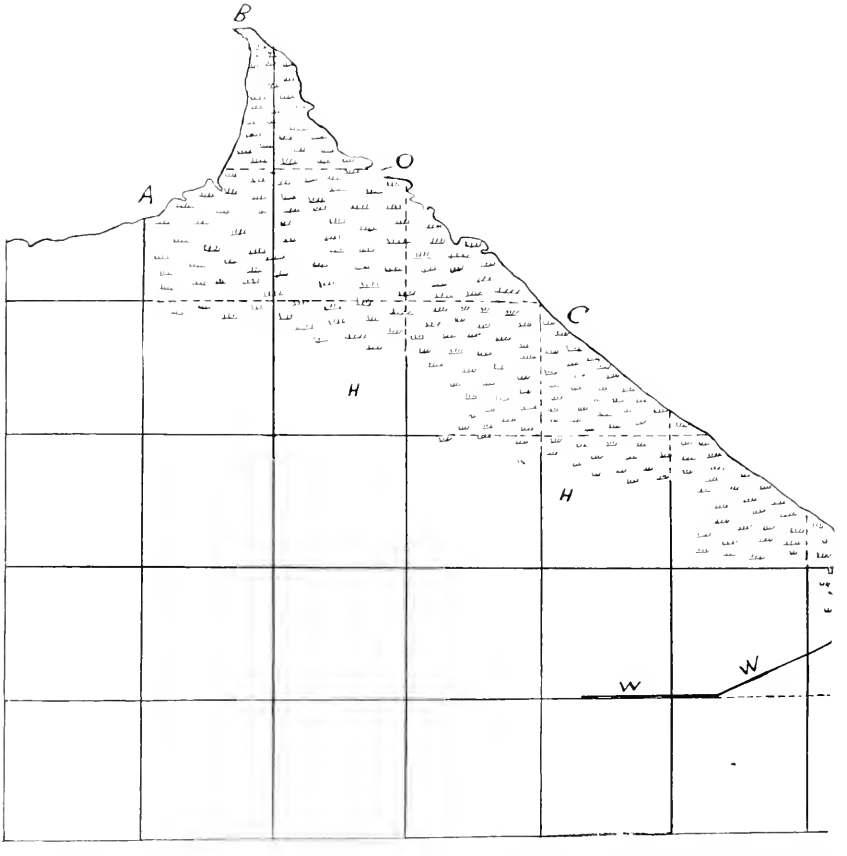


Figure 1. Map of the Toledo Cedar Point, showing the swamp beyond the point B; W, ward canal; H, low ground near swamp; O, open channel into swamp; A, B, C, sandy beach.

THE AMERICAN CHEMIST AND THE WAR'S PROBLEMS.*

JAMES R. WITHROW.

A volume could be written upon this subject if one possessed the power to assemble the material. The new problems which have arisen; the old ones which have become acute because of changed conditions; the splendid way in which the problems have been met where they were a matter of invention or skill; the new methods and processes which have sprung up as though born fullgrown; the many old ones which have been improved, altered and utilized in new connections; the way in which the chemists of the country have risen to emergencies which have compelled them to manufacture products in whose manufacture they had had no prior experience, would easily fill entire chapters in such a volume. Even so, no earthly progress, achievement or consideration can lift the pall which settles over us when we permit our minds to dwell upon the spectacle of this war. And whose mind can be diverted from it for any length of time? He must indeed exist far below the kindling-point who does not resent and despise with all his soul, the philosophy and ideals which made it possible. It would be out of place therefore, to consider our subject from the point of view of achievement, or felicitation, on any alleged good which has come to the science of chemistry because of the war. Surely no one would want progress at such a cost to his fellow man. We approach the subject rather in a spirit of thankfulness that we have been enabled to save something out of the wreck, and that our experience had prepared us in advance so that we have been enabled to prevent the collateral business and economic tragedies of the war from spreading universally. It is not in any spirit of gladness, therefore, at the evil providence which has fallen upon our European neighbors, that we recognize that this war has exalted the importance of chemistry in the minds of those who had not much opportunity hitherto to appreciate its value, nor is it with any jubilation that we take pleasure as chemists in meeting our new problems and emergencies arising from the war.

* Address before Section C, American Association for the Advancement of Science, Columbus Meeting, Dec. 30, 1915.

The satisfaction to many Industrial Chemists in the last two years of being able to contribute to the solution of these problems and of being conscious of the salvation of many businesses from financial ruin through the exercise of their chemical experience, has seldom been so widely distributed as it now is. What an inspiration it would be to read, spread out upon the pages of such a book, as we have mentioned, the chemical successes, big or little, of the past two years. It is not likely that many of them will be known for a while because of the fact that business caution forbids their publicity in many cases, and the vigorous campaign of destruction of equipment and diversion of supplies which stoops at nothing which will hamper export from this country, makes silence a necessity in self defence.

The problems of the war are of two kinds, those due to changed conditions and those arising from supplying munitions at high speed. Among the former are changes in raw materials made necessary by the failure of imports or by unusual consumption of raw material in other channels such as for products not heretofore manufactured in this country to the extent made necessary under present war conditions. These changed circumstances were also due in part to new demands for materials and products, which have arisen in the complete rearrangement of things that has come about in many circles since the war began. The other line of war problems which have arisen, those directly connected with munitions supply, are frequently of a difficult nature. All these various problems, however, have been met in practically every case with a degree of success which has surprised even ourselves.

Naturally one of the first serious effects of the war on American industries was the stagnation produced by the enforced cessation of exports in various lines. Such things as rosin, turpentine, petroleum products, acetate of lime and methyl alcohol were seriously affected for a varying length of time. Then the demand for munitions became, for instance, the wood distillation industry's salvation and with great celerity, acetone plants were attached to many of the works of this industry and the high prices which the products of the industry demanded have brought unprecedented prosperity to it and have correspondingly hampered progressive improvement.

Production, not efficiency, is at present the slogan for this and many other industries. Set-backs of the nature cited usually take time for readjustment and frequently the chemist is a material factor therein. The producer himself is often compelled to add the next manufacturing step to his own operations. The acetate maker for instance, tends to enter acetone manufacturing. Where the new demands were ample, these attempts have succeeded and the war's conclusion will find an increased tendency to manufacture at the source.

The set-backs to industry arising from the disturbance in exports while they were important financially were minor matters compared with those arising from such changed conditions as failure of raw materials or their curtailment by absorption in new or abnormally expanded industries. It is here that the chemist is needed most and it is here that he has been of immeasurable service, and has met the problems that have arisen in wonderful style. He was seriously hampered at first by the uncertainty as to the facts. The fundamental thing in every industry is the market. At first much damage was wrought and delay produced by false reports as to stocks on hand and supply, particularly, of imports. Much withholding of goods for higher prices was practiced and even yet the pirates of commerce seek ways and means of evading contracts, even on deliveries of goods which they were receiving without cessation, so as to avail themselves of the inflated market prices. Some clever work by consumers trapped at least some of these unscrupulous brokers and sellers. All manner of fictitious prices were demanded of those unfamiliar with the facts and attempts were even made to influence the Washington Government to activity against the British blockade through the use of untruthful statistics regarding dyes.

As soon as the true status of market and supply became reasonably certain many changes were effected which will give gradual and probably ultimate relief. On every hand we see chemical activity without end. Products like synthetic phenol and barium salts not made in this country before the war are now made in large amount. Great expansion in production has taken place in the case of such material as benzol, toluol, aniline products, naphthaline, carbon-tetra-chloride, acids, alkalis, chlorates, bichromates and even oxalic acid. With all of these we were largely or in part dependent on imports, but have

almost ceased to be so since the war began. Fertilizer plants erect their own sulfuric acid works and insecticide makers their own arsenic acid plants. Textile mills make their own bleach. Numbers of manufacturers replace potash compounds by sodium compounds and to my own surprise at least, often with great improvement in results. Professor Watts has just told you this afternoon how the ceramist is rendering this country less and less dependent upon imports in that field by scientific purification and utilization of domestic clays. Manufacturers of numerous miscellaneous chemicals and pharmaceutical preparations proceed to refine and produce their own crude raw materials and intermediates. The dye famine—for it is real in certain quarters, stirs up corporations with capital of hundreds of millions to enter the field. One of these new companies has installed half a million worth of machinery in the last few weeks. Indigo and other dyes are being made in nearly half ton batches which will soon expand to several ton size. Where formerly was the most peaceful of occupations even fertilizer manufacture, every effort now goes to the making of munitions. New plants spring up at the beck and call of the new conditions such as the world has never seen. Think of a battery of one hundred nitric acid stills each charging 4,000 lbs. of sodium nitrate three times a day. Think of the sulfuric acid required and the nitric acid produced. Think of the fact that this one of a number such, (the largest nitric acid plant in the world it is said), is a plant which a year ago did not exist except in the minds and plans of a group of chemical engineers. How little are we able to comprehend the reality of producing 1,000,000 pounds per day of gun-cotton where a year ago was merely pine-woods. What does it mean with reference to design of plant, erection and operation to anyone who has not managed chemical engineering operations, to recount the engineering operations involved in this enormous production of gun-cotton in a single plant? Work that is conducted in ten to fifteen parallel procedures or "cotton-lines," which with their accompanying accessories, include cleaning and alkali digestion of the cotton; bleaching with chloride of lime; manufacture of sulfuric acid for the production of nitric acid and "mixed acid;" nitration of the cotton in thirty pound batches; the hazardous wringing and hasty submerging of the cotton in water, to avoid the consequences of

heating by too slow dilution of the strong acid held spongelike by the cotton; the conveying of this material in the cotton-line to the washers where the remaining acid in the tube-shaped cotton fibres is removed; and finally the removal from the water as wet or damp gun-cotton, the commercial product of many plants. This end product of course is but the beginning or raw material for the various nitro-celluloses, smokeless powders and other high explosives. Yet this scale of operations is not going on in just one plant of this kind or even in this one industry. *This* is a sample of what is happening every day in the shape of the American chemical engineers' answer to the question, how are you meeting the war's problems?

At some of these things we are permitted to take at least a peep. No one man can know all of even such gross developments, and practically every chemist we meet has his enthusiastic story of the progress in his own and familiar fields. We all do know, however, that if this is the character of the outward developments, there must be legions of quiet research and other experimental attacks on the new problems, and literally hundreds of solutions being worked out for minor problems in factory and plant, not to speak of the vast amount of work in other departments of chemistry made necessary by all these things. Then, too, there is the ever verdant crop of interesting suggestions, revolutionary changes and inventions throughout the list of the chemical industries. In fact they are doubly numerous and aggressive under the stimulation of such a time as this. It is never wise to predict their success or failure until even years have elapsed in many cases. So that the lecturer who wishes to entertain his hearers with pleasant and surprising intellectual gymnastics in the shape of the newest and most wonderful achievements in industrial chemistry is safe from apparent error for from three months to three years, if he picks his illustrations well. At the end of that time he can dodge criticism for misjudgement by referring the back-fires to poor business management, insufficient capital, tariff, trusts and sometimes poor engineering. It is true that a large number of these new things *never* make good. It is equally true that some of them will make good and that all of them indicate progress, for they are striving, and progress comes by striving.

It is equally true also that many of the chemical experiments which are in successful use under war conditions, will auto-

matically step aside when normal conditions resume. It is fundamental industrial chemical intelligence that a procedure which is ridiculous under some conditions may be a God-send under others. We do not expect every change installed to be really normal progress for it will not be so in the ordinary sense at least. On the other hand, it would be wrong also to say that the mushroom plants producing munitions are not signs of progress. They unquestionably are not such signs in as far as they are temporary. They do not measure true expansion in their respective fields. He would be a novice or singularly blind, however, who did not see that the construction of such plants on the undreamed scale I have already mentioned, not to talk of the new materials and procedures which have been incorporated into many of them, makes for greatly enlarged experience in chemical engineering designing, construction and operation. It is easy to see the pressure these things are going to exert upon the future development of American chemical industries. The American chemist's experience is becoming greatly expanded and the significance of this is apparent when we consider that engineering progress is a function of demand, and skill or experience in solving problems. The demand increment is ever expanding with the development of the country. In addition the skill acquired in the production of munitions is a valuable potential asset for defense should such a necessity ever arise. Such preparedness is highly to be desired. Then too at the close of the war when the output of these plants is no longer needed for that purpose, their equipment and intelligence will be directed into whatever field promises most. Already some of these concerns are assured that some of their products will find a continuous demand after munitions' manufacturing ceases, which will be some little time after actual hostilities are at an end. The field of dye production is already attracting some of them. Without doubt the industrial rearrangements to follow the war will leave us much better situated in our ability to cope with the problems of chemical production. At any rate powerful financial interests will attack these problems as they never have been attacked before. These interests will constitute another great force, which will be particularly effective after the war. When they seek new outlets for materials, such as alcohol, benzol and acids, whose production they are greatly

accelerating at the present, the gasoline and other problems will be greatly affected. These interests will be found after the war lined up behind the industrial chemists who have been struggling for years against all kinds of unfair competition and disreputable depreciation. Then again, any change in process, be it ever so time-worn, chemistry or transient in its nature, if it actually is put into successful operation under the then existing conditions, must of necessity push out the boundaries of experience to greater and greater distances and make us better able to meet the problems of the future. Chemical engineering is like any other division of engineering, it grows by what it accomplishes. In this proof of ability to meet a transient emergency the American chemist is certainly reaping a hundred-fold, from his unadvertized care in the meeting of his industrial problems of the years which have gone before. Individual cases of progress and development which I have mentioned it is easily seen are rarely of great importance in themselves. We have not been revolutionizing on a great scale, nor have we been jumping at once into great new national industries, but we are rather directing the normal steady gait of our progressive industrial development with keener perception toward more complete selfcontainedness, and thorough industrial preparedness. Some of the industries mentioned which receive much public attention are of relatively little importance compared with many other items affected. The dyestuff shortage appears to annoy many, but the complaint is out of all proportion to the facts and the damage done, compared with that of other commodities. We import annually for instance, $9,000,000 in coal tar dyes per annum and if we should make them all ourselves—which we will only gradually approximate—we would only increase our chemical manufactures two per cent. and our total manufactures five one-hundredths of one per cent.

Though we have made reasonable headway on our problems we are keenly aware that much remains to be done. We do not expect to set the market right in the dye or other matters in a year or two. These developments take time and have always taken time. Neither should we deceive ourselves or the public into thinking because of what we are doing that we could turn out without the most careful and detailed previous planning,

adequate munitions for our own defense "in sixty days" to supply the "two million men who would spring to arms" as we so often hear would happen in that undesired emergency.

It would be interesting to discuss in detail some of the transient as well as probably permanent advances, where they happen to be a matter of personal knowledge, if it were wise to hand information to the assassins who lie in wait to hamper some of them, for military reasons. It might be well, therefore, to spend just a little time in emphasizing some general considerations which are connected with this subject.

There is little use in attempting to disguise the fact that the present war is a struggle between the industrial chemical and chemical engineering genius of the Central Powers and that of the rest of the world. Quite irrespective of the war's origin, aims, ideals or political circumstances, these are the cohorts from which each side derives its power.

When we consider the strategic position of the Central Powers themselves, their capable education and training, their system of government, which, no matter what we may think of its selfish effect on the world as a whole, we must admit makes for more effective concentration upon its own governmental objectives, among which preparation for war is merely one of its manifestations, when we take into account all these things it must often appear to us that the greatest outstanding feature of the past two years is the miracle of the Entente Powers resistance to the terribly efficiently prepared onslaught of the Central Powers. This resistance is due, to an extremely large extent, to the efficiency of the chemists of the neutral and Entente nations. The chemists of the Entente Powers and of America have risen to the emergency as no chemists have ever done before in the history of the world. Confronted at the beginning of the war by antagonists whose munitions industry for years had been developed for just such a contingency, these chemists have in less than two years built up a rival industry at least as strong. Plant after plant has sprung up of such perfection of design and operation that one wonders how the mind of man was capable of such engineering. Though the speed with which these new and unexpected problems have been solved may appear surprising, no one who is informed about the progress and development of industrial chemistry in this

country, could have reason to doubt that American chemical engineers and industrial chemists would rise to any emergency which it was within human power to meet. They have already and will continue to live up to what we have a right to expect of them, in view of their past successes. We would be surprised if a similar degree of success did not crown the efforts of the chemists of the other countries, France, Britain, Italy, Germany, Austria, Russia, for it has never been the habit of American chemists to boastingly claim superiority because of any advantage, real or imaginary, with which they, like any group, are apt to be blessed for a greater or less period of time. We have always appreciated chemical contributions to progress from whatever source they have come and praised unstintingly the individual wherever he may be who has taken a distinct step forward, for we firmly believe this is an important help in advancing the progress of the science.

These general developments are naturally not a matter of public information, except attention is called to them. The chemist works almost entirely beneath the surface of things and only in a few spectacular cases is public attention drawn to his work. It is quite natural therefore that appreciation and praise of foreign chemical achievement and particularly our consistent praise of German achievement to our students by our university teachers of chemistry have been misunderstood, and have prepared a fertile field for foreign propagandas to establish a false impression of the superiority of certain groups of foreign chemists. We would scarcely object to a good-natured adulation of anyone's fatherland and its achievements. Such things always contain good and are stimulating to everyone, and it is a pleasure to hear them when free from arrogance, even when the adulation contains little that is new or even strictly true. When, however, this privilege is abused so that the point of superiority must be made by depreciating American efforts it has a vicious positive result upon the minds of the uninformed, and at times causes great financial loss to them.

If the shortcomings of American chemistry were frankly discussed and compared with foreign successes in a chemical publication, some help might thereby be given to those who could derive benefit from it. When this is *not* frankly done, but simply issued as an incidental *depreciation* of American

chemistry, particularly when discussing foreign chemical achievement, and still worse when in a non-chemical publication, the object can scarcely be rated as creditable.

A good illustration of this is an article published by the *Review of Reviews* for August, 1915, upon "What German chemists are doing to make Germany self-sustaining," by Hugo Schweitzer, who the editor humanely states is an American chemist. Considering the avowed purpose of the article as attempting to influence American public opinion to stop "*all* exports to *all* belligerent nations," the article gives an interesting appreciation of the German chemist's efforts to meet their present problems, but commences to wind up as follows:

"Thus the horrors of war, through the ingenuity of the German chemists, are promoting the legitimate industry of the nation, rendering it more and more independent of foreign conditions, and keeping in the country vast sums formerly spent for imports. *Unfortunately and unexpectedly we cannot record similar advantages for the United States, although we are enjoying peace.*" The inaccuracy of the last statement we hope is no measure of the truthfulness of the article as a whole. If the myth of the overwhelming industrial chemical superiority of German chemists ever was really believed, in that country, the military forces of the Central Powers at least, must marvel at the reason the supposedly inferior foreign industrial chemists have been able to display such astounding ability and speed in meeting the problems of munitions production, particularly too in countries where governmental mobilization of industries was unknown before the war and in America at least, still is unknown. At any rate, it has become evident that lack of advertisement is no sign of lack of ability or activity, and that ability to handle science skillfully and powerfully is not confined to any race or nation. We do not feel that there is much to be gained by confuting claims of the chemical superiority, of foreign countries in this and other similar articles for it is curious how this war has developed farsightedness to the extent that such *Americans* can see only the chemical developments abroad.

I hope I have made it clear that it is the abuse of a privilege against which I speak, and not against individuals, for we do not let such personal attacks affect our regard for individual Germans any more than we allow our opinions on the history

of the past two years to affect this regard for such individuals. Everyone of us knows Germans who are the most whole-souled and kindly men—who we are grateful to know and who scorn to be guilty of, or take advantage of, such chauvinism. Such depreciations of American efforts will bury themselves, without any assistance from us, and I only emphasize them here to call the attention of teachers of chemistry to the fact that *we* owe protection to the business community and the public against such misrepresentation. We should never cease our appreciation of foreign chemists of whatever nation, but in addition it is our duty first to inform *ourselves* and then our students upon what our own chemists have done to solve our problems in this country. We have been able to blame our shirking this duty in the past upon the fact that it was easy to get information about foreign chemical achievement and no one seemed anxious to give publicity to American development. We as teachers have certainly done little to remedy this condition. The American Chemical Society, however, has spread the results of American effort before us and made them accessible in its *Journal of Industrial and Engineering Chemistry* for the last two years, in the shape of a series of addresses on the chemist's contributions to American industries. There are other addresses in these same volumes profoundly informing along these lines and this is particularly true of the Perkin Medal addresses each year in the same journal. In addition, Professor S. P. Sadtler in the *American Journal of Pharmacy* for October, 1915 (an address before the National Exposition of Chemical Industries), in giving popular information along this line limits himself entirely to chemical industries *originated* as well as developed by American chemist and Edgar F. Smith's History of Chemistry in America, but recently issued, should be read by every student of chemistry.

None of this work is in any sense a vain glorious adulation of the chemist as some super-being nor is it an attempt to compete in the questionable game of lauding one nationality above another. It is merely a matter of a belated form of education which our universities and chemists hitherto have largely denied to the American business man, and which he has a right to expect of them. The record is one for which we have good reason to be thankful and, as we teachers no longer have the

excuse of ignorance about American progress, we are at fault, if the rising generation has not an appreciation of the progress of chemistry in America, commensurate with the high level of its development.

In conclusion then, let us take courage from the fact that though much damage has been done to us and our industries by the war, our efforts at salvage benefit us as experience, power and preparedness. We have seen that the chemists of America have met the war situation well and do not require defense at the hands of anyone. It becomes increasingly evident that business is awakened to the value of chemistry as a source of power and wealth as business has never had occasion or opportunity to be hitherto. Let us hope also that not only the spectators but also all the combatants may learn, even if impelled by bitter war's experience, to appreciate the worth, each of the other, and that all nations are "made of one blood to dwell on the face of the earth."

DERIVED SOLUTIONS OF DIFFERENTIAL EQUATIONS.

(Short Methods).

R. D. Bohannan.

When $F(m)=0$ has n roots equal a, then $F(m)=0$ and its first $n-1$ derivatives have this root in common. So if $F(m, x)$ is a solution of a differential equation, for different values of m, then, if n values of m are equal to a, are also the first $n-1$ partial derivatives of $F(m, x)$ with respect to m also, generally, solutions, when, after differentiation, m is changed to a.

CASE I.

(a) Linear differential equations with constant coefficients, second member zero.

$$y=e^{mx}$$

is the solution.

If $(D-a)^n$ is a factor of the first member, using the symbolic method of solution, then

$$e^{mx},\ xe^{mx},\ x^2e^{mx}\ \ldots\ldots\ldots,\ x^{n-1}e^{mx},$$

are all solutions, when m is changed to a, these being the partial derivatives with respect to m. Multiply each of these by an arbitrary constant and add for the general solution corresponding to $(D-a)^n$.

(b) When D^2+a^2 is a factor of the first member,

$$y=\sin\ mx,\ \ y=\cos\ mx$$

are solutions, when m is a.

When $(D^2+a^2)^n$ is a factor of the first member,

$\sin ax,\ x\sin(\pi/2+ax),\ x^2\sin(2\pi/2+ax),\ \ldots\ldots\ldots\ldots\ldots$
$x^{n-1}\sin((n-1)\pi/2+ax),$
$\cos ax,\ x\cos(\pi/2+ax,\ x^2\cos(2\pi/2+ax),\ \ldots\ldots\ldots\ldots\ldots$
$x^{n-1}\cos((n-1)\pi/2+ax)$

are solutions.

(c) When $(D-a)^2+b^2$ is a factor of the first member,

$$y=e^{mx}$$

is a solution, when m is changed to $a+bi$ and $a-bi$, giving,

$$y=e^{ax}\cos bx\quad\text{and}\quad y=e^{ax}\sin bx$$

as solutions, after addition and subtraction.

When $((D-a)^2+b^2)^n$ is a factor of the first member, the $(n-1)$ partial derivatives of e^{mx} with respect to m,

$$xe^{mx},\ x^2e^{mx},\ \ldots\ldots\ldots,\ x^{n-1}e^{mx},$$

are also solutions, when m is $a+bi$, or $a-bi$, giving also as solutions,

$$xe^{ax}\sin bx,\ xe^{ax}\cos bx,\ x^2e^{ax}\sin bx,$$
$$x^2e^{ax}\cos bx,\ \ldots\ldots\ldots,\ x^{n-1}e^{ax}\sin bx,$$
$$x^{n-1}e^{ax}\cos bx.$$

Multiply each by an arbitrary constant and add.

Case II.

For the homogeneous linear differential equation of the form,

$$x^n\frac{d^ny}{dx^n}+x^{n-1}\frac{d^{n-1}y}{dx^{n-1}}+\ldots\ldots+x\frac{dy}{dx}+y=0.$$

$$y=x^m$$

gives $x^n F(m)=0$, and if $m-a$ is a factor of $F(m)$, a solution is

$$y=x^a$$

The partial derviatives of x^m, with respect to m, are

$$x^m\log_e x;\ x^m\log_e^2 x;\ x^m\log_e^3 x,\ \text{etc.}$$

Thus if $(m-a)^n$ is a factor of $F(m)$, the solutions are,

$y=x^a,\ y=x^a\log_e x,\ y=x^a(\log_e x)^2,\ \ldots\ldots\ldots\ldots\ldots\ldots$
$y=x^a(\log_e x)^{n-1}$

Multiply each by an arbitrary constant and add.

Case III.

(a) In (a) of Case I, if the second member is e^{mx} (instead of zero) *the particular solution* is

$$y=\frac{e^{mx}}{D-a}=\frac{e^{mx}}{m-a}$$

for the equation $(D-a)\,y=e^{mx}$.

This fails when $m=a$.

All failing cases of this sort will give a solution when treated like the form $\frac{0}{0}$ in calculus (differentiating as many times as the factor occurs, *omitting differentiation as to factors giving no trouble*, just as in the calculus problem).

(1) $$y = \frac{e^{mx}}{m-a} = \frac{\frac{\partial}{\partial m}(e^{mx})}{\frac{\partial}{\partial m}(m-a)} = xe^{mx} = xe^{ax}$$

(2) $$y = \frac{e^{mx}}{(m-a)^2} = \frac{xe^{mx}}{2(m-a)} = \frac{x^2e^{mx}}{2} = \frac{x^2e^{ax}}{2}$$

(3) $$y = \frac{e^{mx}}{(m-a)^n} = \frac{x^ne^{ax}}{\lfloor n}$$

(4) $$y = \frac{e^{mx}}{(m^2+5m+3)(m-2)^2}, \text{ when } m = 2$$
$$= \frac{xe^{mx}}{(17)\ 2\ (m-2)} = \frac{x^2e^{mx}}{(17)\ (2)} = \frac{x^2e^{2x}}{34}$$

(b) For $(D^2+a^2)\ y = \sin\ (mx)$

(1) $$y = \frac{\sin\ (mx)}{D^2+a^2} = \frac{\sin\ (mx)}{-m^2+a^2}$$

This fails when $m = a$, but

(1) $$y = \frac{\frac{\partial}{\partial m}(\sin\ (mx))}{\frac{\partial}{\partial m}(-m^2+a^2)} = \frac{x\cos\ (mx)}{-2m} = \frac{x\cos\ (ax)}{-2a}$$

(2) $$y = \frac{\cos\ (mx)}{D^2+a^2} = \frac{\cos\ (mx)}{a^2-m^2} = \frac{x\sin\ (mx)}{2m} = \frac{x\sin\ (ax)}{2a},$$

when $m = a$.

(3) $$y = \frac{\sin\ mx}{(D^2+9)\ (D^2+4)} = \frac{\sin\ mx}{(9-m^2)\ (4-m^2)}$$

For $m = 2$,

$$y = \frac{x\ \cos\ mx}{5(-2m)} = \frac{-x\cos 2x}{20}$$

For $m = 3$,

$$y = \frac{x\cos\ mx}{(-2m)\ (-5)} = \frac{x\cos\ 3x}{30}$$

(4) $$y = \frac{\sin\ mx}{(D^2+4)^2}, \text{ when } m = 2$$
$$= \frac{\sin\ mx}{(4-m^2)^2} = \frac{x\cos\ mx}{(-4m)\ (4-m^2)} = \frac{-x^2\sin\ mx}{(-4m)\ (-2m)}$$
$$= \frac{-x^2\sin\ 2x}{32}$$

$$(5)\quad y = \frac{\sin mx}{(D^2+4)^3}, \text{ when } m=2$$

$$= \frac{\sin mx}{(4-m^2)^3} = \frac{x\cos mx}{3(-2m)\ (4-m^2)^2} = \frac{-x^2\sin mx}{3\ (-2m)^2(4-m^2)}$$

$$= \frac{-x^3\cos mx}{3\ (-2m)^3} = \frac{x^3\cos 2x}{3\ (4)^3}$$

$$(6)\quad y = \frac{\sin mx}{(D^2+a^2)^n}, \text{ when } m=a$$

$$= \frac{x^n\sin\left(n\frac{\pi}{2}+mx\right)}{\lfloor n\ 2^n\ (-m)^n} = \frac{x^n\sin\left(n\frac{\pi}{2}+ax\right)}{\lfloor n\ 2^n\ (-a)^n}$$

Similar treatment when the second member is the cosine.

Case IV.

Linear differential equations, constant coefficients, second member a constant.

This is a particular case of (a) Case III.

$$\frac{d^2y}{dx^2} - 5\frac{dy}{dx} + 6y = 4 = 4e^{ox}$$

$$\therefore\ y = \frac{4e^{ox}}{D^2-5D+6} = \frac{4}{6} = \frac{2}{3},$$

when $D=0$, is the particular solution.

Case V.

Failing case of Case IV.

$$\frac{d^2y}{dx^2} - 5\frac{dy}{dx} = 4 = 4e^{ox}$$

$$y = \frac{4e^{mx}}{m^2-5m}$$

is the solution when $m=0$.

$$\therefore \text{ As in Case III, } y = \frac{4xe^{mx}}{2m-5}, \text{ when } m=0$$

$$\text{or, } y = -\frac{4x}{5},$$

is the *particular solution.*

Case VI.

The non homogeneous linear differential equation.

The solution is usually two or more series gotten from.

$y = x^m\ (A_o + A_1,\ x^{n_1} + A_2\ x^{n_2} + A_3 x^{n_3} +$ etc.), (S), (where A_1, A_2, A_3, etc., are functions of m, and each of all the preceding by giving m particular values gotten by substituting x^m for y in the given equation.

Calling (S), $y = F\ (m, x)$, then, in case of two equal roots in m, is

$$y = \frac{\partial}{\partial m} F\ (m, x).$$

a solution, if, after differentiation, m is given the value of this root. And in case of three equal roots, is also

$$y = \frac{\partial^2}{\partial m^2} F\ (m, x)$$

a solution, and so on.

Suppose k is a particular value of m, and that x^m, A_1, A_2, etc., are all expressed in powers of $m-k$:

$$x^m = x^k\ (1 + (m-k) \log_e x + \frac{(m-k)^2}{2} \log^2_e x + \text{etc.})$$

$$A_o = A_o(1 + \text{Zero}\ (m-k) + \text{Zero}\ (m-k)^2 + \text{etc}).$$
$$A_1 = A_o(a_1 + b_1\ (m-k) + c_1\ (m-k)^2 + \text{etc.})$$
$$A_2 = A_o(a_2 + b_2\ (m-k) + c_2\ (m-k)^2 + \text{etc.}),$$

and so on.

Substitute these values for the A's in S and calling $1 + a_1 x^{n_1} + a_2 x^{n_2} +$ etc., the A-series; the coefficient of $m-k$, the B-series; that of $(m-k)^2$, the C-series, etc., (S) becomes:

$$y = A_o x^k\ (1 + (m-k) \log_e x + \text{etc.}) \text{ times}$$
$$(\text{A-series} + (m-k)\ (\text{B-series}) + (m-k)^2\ (\text{C-series})$$
$$+ \text{etc.}) = A_o x^k\ (\text{A-series})$$
$$+ A_o x^k\ (\ (\text{A-series}) \log_e x + \text{B-series})\ (m-k)$$
$$+ A_o\ x^k\ (\frac{(\text{A-series})}{2} \log^2_e x + (\text{B-series}) \log_e x$$
$$+ \text{C-series})\ (m-k)^2 + \text{etc.}$$

In case m has the value k only once,

$$y = A_o\ x^k\ \text{A-series} \qquad (1)$$

is the solution.

If m has the value of k twice,

$$y = B_o x^k\ (\ (\text{A-series})\ \log_e x + \text{B-series}) \qquad (2)$$

is also a solution. This is

$$y = \frac{\partial}{\partial m} F\ (m, x)$$

when $m = k$.

And thus is

$$y = x^k\ (A_o + B_o \log_e x)\ \text{A-series} + B_o x^k\ (\text{B-series})$$

a solution.

And in case m has the value k three times, then in addition to the solutions (1), (2), is also

$$y = C_o x^k \frac{(\text{A-series})}{2} \log_e^2 x + (\text{B-series}) \log_e x + (\text{C-series})$$

a solution. This is

$$y = \frac{\partial^2}{\partial m^2} F\ (m, x) \text{ when } m = k$$

And thus is

$$y = x^k\ (A_o + B_o \log_e x + \frac{C_o}{2} \log_e^2 x)\ (\text{A-series})$$
$$+ x^k (B_o + C_o \log_e x)\ (\text{B-series})$$
$$+ x^k\ (\text{C-series})$$

a solution. And so on.

It is quite easy, in any particular case, to obtain the B-series, C-series, etc., from the A-series, far easier than by the method usual in the texts (compare the following with Johnson, p. 181 to 194).

Illustrations.

(a) Series starting with x^o.

$$x \frac{d^2y}{dx^2} + \frac{dy}{dx} + y = 0$$

$$y = x^m, \text{ gives } m^2 x^{m-1} + x^m = 0 \qquad (1)$$

We may assume an ascending series, starting with x^o, consecutive powers differing by unity.

If we assume $y = \sum_0^\infty A_r x^{m+r}$,

then by (1)

$$(m+r)^2 A_r + A_{r-1} = 0$$

$$\therefore A_r = -A_{r-1} \frac{1}{(m+r)^2} \qquad (2)$$

For $m = 0$, $A_r = -A_{r-1} \cdot \frac{1}{r^2}$ (3);

(3) gives the A-series,

$$y = 1 - \frac{x}{1^2} + \frac{x^2}{1^2.2^2} - \frac{x^3}{1^2.2^2.3^2} + \text{etc.}$$

If we differentiate the m-factor, $-\frac{1}{(m+r)^2}$, occurring in (2), we have

$$\left(\frac{1}{(m+r)^2}\right)\cdot\left(\frac{2}{m+r}\right)$$

And for $m=0$, this is

$$\left(-\frac{1}{r^2}\right)\left(-\frac{2}{r}\right)$$

And the nth term of the B-series comes at once from the $(n+1)^{th}$ term of the A-series (beginning with the 2d term of the A-series) by multiplying by

$$\sum_1^n \left(-\frac{2}{r}\right)$$

So that the B-series is

$$2\frac{x}{1^2}-3\frac{x^2}{1^2.2^2}+\frac{11}{3}\cdot\frac{x^3}{1^2.2^2.3^2}-\frac{25}{6},\ \frac{x^4}{1^2.2^2.3^2.4^2}+\text{ etc.}$$

As this method of getting the B-series from the A-series gives the relation of corresponding terms, it makes the settlement of the question of the convergency of the B-series much easier than Johnson's method. Into the question of convergency I am not entering here, but merely showing how to get the B-series, whether or not it is a usable solution.

The reason for the above procedure is this: The A's come each from the preceding by multiplication:

$$\begin{aligned}
A_1&=A_o(1+g_1(m-k)+\text{ etc.})\\
A_2&=A_1(1+g_2(m-k)+\text{etc.})\\
&=A_o(1+(g_1+g_2)\ (m-k)+\text{etc.})\\
A_3&=A_2(1+g_3(m-k)+\text{etc.})\\
&=A_o(1+(g_1+g_2+g_3)\ (m-k)+\text{etc.})
\end{aligned}$$

and so on.

The coefficient of $m-k$ in A_n is $\sum_1^n g_n$.

And since, in the expansion, the coefficients of $m-k$ are values of $F'(m)$, the B-series comes from the A-series by the relation $\sum_1^n F'(m)$ using the m factor of A_{r-1}, as in the foregoing example.

(2) $x(1-x^2)\frac{d^2y}{dx^2}+(1-3x^2)\frac{dy}{dx}-xy=0$ (Johnson-181)

$y=x^m$ gives $m^2x^{m-1}-(m+1)^2\,x^{m+1}=0$ (E)

And we may thus assume an ascending series beginning with $m=0$, or a descending series beginning with $m=-1$, exponents differing by 2 in each case.

(1) The ascending series,

$$y = \sum_{0}^{\infty} A_r x^{m+2r}$$

gives, by (E),

$$(m+2r)^2 A_r - (m+2r-1)^2 A_{r-1} = 0$$

$$\therefore A_r = \frac{(m+2r-1)^2}{(m+2r)^2} \cdot A_{r-1} \quad (2)$$

$$\text{For } m=0,\ A_r = \frac{(2r-1)^2}{(2r)^2} A_{r-1} \quad (3);$$

(3) gives the A-series.

Differentiating the m-factor of (2) we have

$$\left(\frac{(m+2r-1)^2}{(m+2r)^2}\right) \quad \left(\frac{2}{(m+2r)\ (m+2r-1)}\right)$$

And for $m=0$, this is

$$\left(\frac{(2r-1)^2}{(2r)^2}\right) \quad \left(\frac{1}{r(2r-1)}\right)$$

And thus the nth term of the B-series is derivable from the $(n+1)^{th}$ term of the A-series, beginning with the 2d, by multiplying by

$$\sum_{r=1}^{r=n} \frac{1}{r(2r-1)} \quad (4)$$

By (3) the A-series is

$$y = 1 + \frac{1^2}{2^2} x^2 + \frac{1^2.3^2.}{2^2.4^2} x^4 + \frac{1^2.3^2.5^2}{2^2.4^2.6^2.} x^6 + \text{etc.}$$

And by (4) the B-series is

$$\frac{1^2}{2} x^2 + \frac{7}{6} \frac{1^2.3^2.}{2^2.4^2.} x^4 + \frac{37}{30} \cdot \frac{1^2.3^2.5^2.}{2^2.4^2.6^2.} x^6 + \text{etc.}$$

(2) The descending series for the same equation.

$(m+1)^2 x^{m+1} - m^2 x^{m-1} = 0$, gives,

$$(m-2r+1)^2 x^{m-2r} A_r - (m-2r+2) x^{m-2r-1} A_{r-1} = 0$$

$$\therefore A_r = \frac{(m-2r+2)^2}{(m-2r+1)^2} A_{r-1} \quad (1)$$

$$\text{For } m=-1, \qquad A_r = \frac{(2r-1)^2}{(2r)} A_{r-1} \quad (2)$$

This gives the A-series.

Differentiating the m-factor of (1)

$$\left(\left(\frac{m-2r+2}{m-2r+1}\right)^2\right) \quad \left(\frac{-2}{(m-2r+1)\,(m-2r+2)}\right)$$

For $m=-1$, this is

$$\left(\left(\frac{2r-1}{2r}\right)^2\right) \quad \left(-\frac{2}{2r\,(2r-1)}\right)$$

And thus the nth term of the B-series is derived from the $(n+1)^{th}$ term of the A-series, beginning with the 2d, by multiplying by

$$\sum_1^n \frac{-2}{(2r-1)\,(2r)}$$

The A-series is

$$x^{-1}\ (1+\frac{1^2}{2^2}x^{-2}+\frac{1^2.3^2.}{2^2.4^2}x^{-4}+\text{etc.})$$

And the B-series is

$$-2x^{-1}\ (\frac{1^2}{2^2}\cdot\frac{1}{1.2}x^{-2}+\frac{1^2.3^2}{2^2.4^2}\left(\frac{1}{1.2}+\frac{1}{3.4}\right)x^{-4}+\text{etc.})$$

(b) Series starting with the same value of m, but not zero.

$$x^2\frac{d^2y}{dx^2}-3x\frac{dy}{dx}+(4-x)\,y=0$$

$y=x^m$ gives $(m-2)^2\,x^m-x^{m+1}=0$.

$\therefore$ Two ascending series, starting with x^2,

$$A_r=\frac{A_{r-1}}{(m+r-2)^2} \qquad (1)$$

$$\text{For } m=2,\ A_r=,\ A_{r-1}\left(\frac{1}{r^2}\right) \qquad (2);$$

(2) gives the A-series.

Differentiating the m-factor of (1),

$$\left(\frac{1}{(m+r-2)^2}\right) \quad \left(\frac{-2}{m+r-2}\right)$$

For $m=2$, this is

$$\left(\frac{1}{r^2}\right) \quad \left(-\frac{2}{r}\right)$$

The nth term of the B-series is derivable from the $(n+1)^{th}$ term of the A-series by multiplying by

$$\sum_1^n\left(-\frac{2}{r}\right)$$

The A-series is

$$x^2\left(1+\frac{1}{1^2}x+\frac{1}{1^2.2^2}x^2+\frac{1}{1^2.2^2.3^3}x^3+\text{etc.}\right)$$

And the B-series is

$$-2x^2\left(\frac{x}{1^2}+\frac{3}{2}\cdot\frac{1}{1^2.2^2}x^2+\frac{11}{6}\cdot\frac{1}{1^2.2^2.3^2}x^3+\text{etc.}\right)$$

Note—Equations of the sort that give two or more solutions starting with a value of m different from zero, can be reduced to the latter sort in two ways. First, by a change of the dependent variable. If the starting value is x^k, set $y=x^k y$. The equation just considered, if we set $y=x^2y$, becomes

$$x\frac{d^2y}{dx^2}+\frac{dy}{dx}-y=0,$$

and $x^m=y$, gives $m^2\,x^{m-1}-x^m=0$

$$\therefore A_r=\frac{1}{(m+r)^2}\cdot A_{r-1}$$

$$\text{For } m=0,\ A_r=A_{r-1}\left(\frac{1}{r^2}\right)$$

This gives the A-series.

Differentiating the m-factor,

$$\left(\frac{1}{(m+r)^2}\right)\quad\left(\frac{-2}{m+r}\right)$$

becomes, for $m=0$,

$$\left(\frac{1}{r^2}\right)\quad\left(\frac{-2}{r}\right)$$

The B-series is derivable from the A-series by

$$\sum_1^n\left(\frac{-2}{r}\right)$$

The resulting two series multiplied by x^2, give the required A-series and B-series.

Or, we might change $m-k$ to n, and deduce the series in terms of n as heretofore in terms of m. Thus case (b) is always reducible to case (a).

(c) Series starting with values of m differing by a multiple of s when

$$y=\sum_0^\infty A_r x^{m+rs}$$

is the assumed solution.

(Compare Johnson, p. 185–9).

$$x^2(1+x)\frac{d^2y}{dx^2}+x\frac{dy}{dx}+(1-2x)\,y=0$$

(Compare Johnson, p. 185).

$y=x^m$, gives

$$(m+1)\,(m-2)\,x^{m+1}+(m^2+1)\,x^m=0 \qquad (1)$$

And we may select two descending series, beginning with x^{-1} and x^2, with powers differing by unity.

By (1), $y=\sum_1^\infty A_r x^{m-r}$ gives

$$(m-r)\,(m-r-3)\,A_{r+1}+((m-r)^2+1)\,A_r=0$$

$$\therefore A_{r+1}=-\frac{(m-r)^2+1}{(m-r)\,(m-r-3)}A_r \qquad (2)$$

For $m=2$, this gives,

$$A_{r+1}=\frac{(2-r)^2+1}{(2-r)\,(r+1)}A_r$$

And this will fail when $r=2$

For $m=-1$, (2) gives

$$A_{r+1}=-\frac{(r+1)^2+1}{(r+1)\,(r+4)}A_r \qquad (3)$$

This gives the A-series, from which, by the method already used, we can also get the B-series.

Differentiating the m-factor of (2)

$$\left(-\frac{(m-r)^2+1}{(m-r)\,(m-r-3)}\right)\left(-\frac{3(m-r)^2+2(m-r)-3}{(m-r)\,(m-r-3)\,((m-r)^2+1)}\right)$$

When $m=-1$, this becomes

$$\left(-\frac{(1+r)^2+1}{(r+1)\,(r+4)}\right)\left(-\frac{3r^2+4r-2}{(r+1)\,(r+4)\,(r^2+2r+2)}\right)$$

Thus the terms of the B-series (except as to those preceding the A-series) are gotten, the nth term of the B-series from the $(n+1)^{th}$ term of the A-series by multiplying by

$$-\sum_0^n\frac{3r^2+4r-2}{(r+1)\,(r+4)\,(r^2+2r+2)}$$

The A-series is

$$x^{-1}\left(1-\frac{2}{1.4}x^{-1}+\frac{2}{1.4}\cdot\frac{5}{2.5}\cdot x^{-1}+\text{ etc.}\right.$$

And the B-series is

$$x^{-1}\left(-\frac{1}{4}\cdot\frac{2}{1.4}x^{-1}+\frac{3}{20}\cdot\frac{2}{1.4}\cdot\frac{5}{2.5}x^{-2}-\text{ etc.}\right.$$

To get the terms of the B-series preceding the A-series,

$$A_r=-\frac{(m-r)\,(m-r-3)}{(m-r)^2+1}A_{r+1},\text{ by (2)}$$

Differentiating

$$A_r=-\frac{(m-r)\,(m-r-3)}{(m-r)^2+1)}A_{r+1}\cdot\left(\frac{3(m-r)^2+2(m-r)-3}{(m-r)\,(m-r-3)\,((m-r)^2+1)}\right)$$

And when $m=-1$, this is

$$A_r=-\frac{(1+r)\,(4+r)}{r^2+2r+2}\cdot A_{r+1}\left(\frac{3r^2+4r-2}{(1+r)\,(4+r)\,(r^2+2r+2)}\right)$$

$$\therefore A_r=A_{r+1}\left\{-\frac{(1+r)\,(4+r)}{r^2+2r+2}-\frac{3r^2+4r-2}{(r^2+2r+2)^2}(m+1)+\text{ etc.}\right\}$$

$$\therefore A_{-1}=A_0\,(0+3\,(m+1)$$

$$A_{-2}=A_{-1}\,(1+k_1\,(m+1)+\text{ etc.}$$

$$=A_0\,(0+3\,(m+1)+\text{ etc.})$$

$$A_{-3}=A_{-2}\left(\frac{2}{5}+k_2\,(m+1)+\text{ etc.}\right)$$

$$=A_0\left(0+\frac{6}{5}(m+1)+\text{ etc.}\right)$$

$$A_{-4}=A_{-3}\,(0+k_3\,(m+1)+\text{etc.})$$

$$=A_0\,(0+0\,(m+1);$$

and all subsequent terms vanish as to $m+1$.

$\therefore$ terms to be added are

$$B_0\left(3+3x+\frac{6}{5}x^2\right)$$

Vanishing of the first term in A_{-1} prevents using the procedure used heretofore, since in this case a summation no longer holds.

(2)
$$4x\,(1-x)\frac{d^2y}{dx^2}-4\frac{dy}{dx}-y=0$$

$y=x^m$ gives

$$4m\,(m-2)\,x^{m-1}-(2m-1)^2\,x^m=0$$

$\therefore$ series start with x^0 and x^2; exponents of powers differ by unity.

$$A_r = \frac{(2(m+r)-3)^2}{4(m+r)\ (m+r-2)} A_{r-1} \qquad (1)$$

For $m=0$, the series would fail for $r=2$.

For $m=2$

$$A_r = \frac{(2r+1)^2}{2r\ .\ 2(r+1)} A_{r-1} \qquad (2)$$

This gives the A-series.

Differentiating (1)

$$A_r = \frac{(2(m+r)-3)^2}{4(m+r)\ (m+r-2)} A_{r-1} \frac{2(m-r)-6}{(m+r)\ (m+r-2)\ (2(m+r)-3)}$$

And when $m=2$, this is

$$A_r = \frac{(2r-1)^2}{2r\ .\ 2(r+2)} A_{r-1} \cdot \frac{2(r-1)}{r(r+2)\ (2r+1)}$$

The B-series derivable from the A-series is gotten thus: The nth term of the B-series from the $(n+1)^{th}$ term of the A-series by multiplying by

$$\sum_1^n \frac{2(r-1)}{r(r+2)\ (2r+1)}$$

And the terms of the B-series preceding the A-series come from

$$A_{r-1} = A_r \left(\frac{2r\ .\ 2(r+2)}{(2r+1)} - \frac{8(r+1)}{(2r+1)3}\ (m-2) \right)$$

$$\therefore A_{-1} = A_0\ (0+8(m-2)\ )$$

$$A_{-2} = A_{-1}(-4-16(m-2)\ )$$

$$= A_0(0-32(m-2)\ )$$

$$A_{-3} = A_{-2}(0+k(m-2)$$

$$= A_0(0+0(m-2)\ )$$

$\therefore$ the terms are

$$B_0(-32+8x)$$

THE ELECTRICAL CONDUCTIVITY OF INDIUM AND THALLIUM.

ALPHEUS W. SMITH.

The behavior of the electrical conductivity of metals when the metal passes from the solid to the liquid condition is of increasing interest and importance in the formation of an electron theory of metallic conduction. Except for the excellent work of Northrup,* little systematic work has been done in this field. It is the purpose of this short paper to give some results obtained for indium and thallium.

In order to make possible observations on the metal in the liquid as well as in the solid condition, the metal to be studied was introduced into a glass tube one end of which was closed. Four platinum wires were sealed into this tube so that they were at right angles to its axis. Two of these wires served as potential and two as current electrodes in the ordinary Thomson double bridge method of comparing low resistances. This glass tube was about 3 mm. in internal diameter and the distance between the potential electrodes was about 2 cm. A sufficient quantity of the metal was introduced to fill the tube above the platinum electrode farthest from the closed end. The air was exhausted from the tube and it was then sealed off to prevent the oxidation of the metal on fusion. After fusion the metal was allowed to cool slowly from the liquid to the solid state.

In order to secure the necessary temperatures for these observations a cylindrical electrical furnace wound with nichrome wire was used, except for room temperature and the temperature of melting ice. The temperatures were determined by means of a mercury in glass thermometer which was filled with nitrogen. The observations on the resistances were made in the usual way with a Thomson double bridge which was obtained from Wolff. The standard low resistance was a coil had a resistance of 0.001 ohm at 20 C. The indium and thallium were obtained from Merck & Co. No chemical analysis was made of them and no attempt to further purify them.

* Jour. Franklin Inst. 175, pp. 153 161 (1913).

In order to calculate the specific resistance of the indium the specific resistance at 0° C. was taken as 8.37×10^{-6} ohms. This is the value found by Erhard† who made his observations on indium in the form of wires. Taking this value as known the value of the specific resistance for any other temperature could be at once calculated. In the case of thallium the value by Dewar and Fleming‡ was assumed to be correct. These

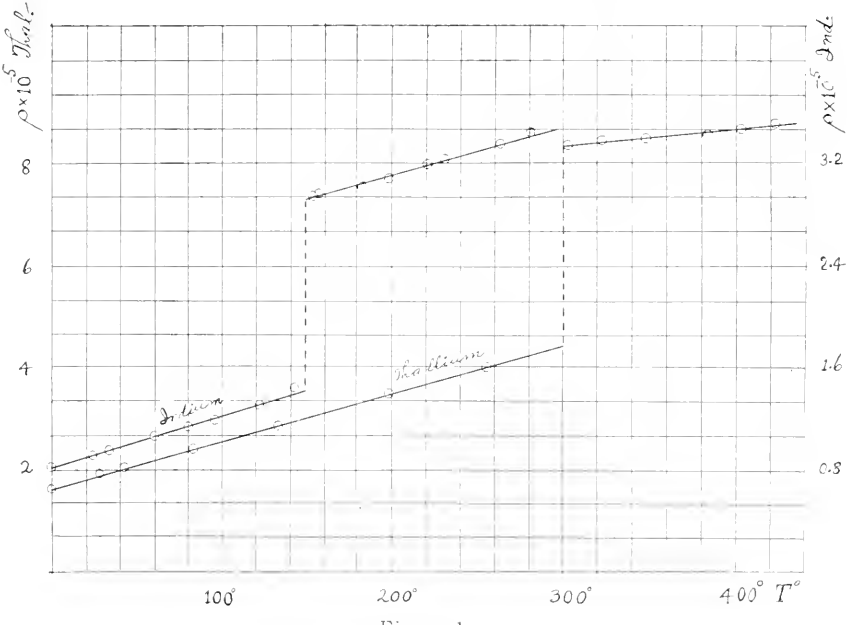


Figure 1

observers found the specific resistance of thallium to be 17.60 $\times 10^{-6}$ ohm at 0° C. From this value the other values for the specific resistance were calculated.

The results of these observations have been given in Table I and have also been plotted in the accompanying figure 1 in which the ordinates are the specific resistances in ohms and the abscissæ are the temperatures. Some of the observations were made with increasing and some with decreasing temperature. In each of these cases is seen the characteristic discontinuity in the curve at the melting point of the metal. In each of these

† Erhard, W. A., 14 p. 504 (1881).

‡Dewar and Fleming, Phil. Mag. (5) 36, p. 271 (1893).

two metals the resistance in the solid as well as in the liquid state is nearly a linear function of the temperature. The rate at which the resistance increases with the temperature is less in the liquid than in the solid state.

TABLE I.

Indium		Thallium	
Temp.	$\rho \times 10^6$	Temp.	$\rho \times 10^6$
0°	8.37	0°	17.60
24.1	9.27	28.4	19.59
34.7	9.62	41.8	21.11
60.2	10.85	45.1	21.31
80.4	11.48	83.0	24.46
86.4	11.98	84.7	24.62
121.4	13.09	133.2	28.72
141.8	14.56	135.0	29.09
142.7	14.63	197.5	35.10
154.0	29.10	198.0	35.14
156.8	29.28	254.0	40.16
166.8	29.66	258.2	40.22
181.5	30.11	301.7	83.38
182.8	30.13	302.5	83.60
198.5	30.84	305.5	83.61
220.0	31.87	309.0	83.89
230.0	32.29	321.0	84.32
261.0	33.31	347.0	84.84
280.2	34.87	356.0	85.35
		367.4	85.34
		382.0	85.95
		401.5	86.78
		422.0	87.54

TABLE II.

Metal	$\frac{1}{R_0}\left(\frac{\partial R}{\partial t}\right) \times 10^3$	$\frac{1}{R_0}\left(\frac{\partial R}{\partial t}\right) \times 10^3$	$R_1 R_s$
Indium	5.24	3.98	2.00
Thallium	5.27	1.95	1.90

Table II gives the temperature coefficient of the resistance of thallium and indium before and after melting. The second column gives this coefficient before melting; the third column, after melting. In the last column of this table is the ratio of the resistance before and after fusion. Within the error of observation this ratio is 2.00 for indium and 1.90 for thallium.

The temperature coefficients of the resistance here recorded are somewhat larger than those found by Erhard for indium and by Dewar and Fleming for thallium. The former working between —5.4° C. and 96° C. gives for the temperature coefficient of indium 4.77×10^{-3}, the latter working between 0° and 100° gives for the temperature coefficient of thallium 3.98×10^{-3}. These discrepancies are probably due to impurities and to mechanical treatment of the specimens.

I wish to express my thanks to the Rumford Committee which bore part of the expense of this investigation.

Physical Laboratory, Ohio State University.

NEWS AND NOTES.

THE OHIO ACADEMY OF SCIENCE. The Annual Meeting of the Ohio Academy of Science was held on April 21st and 22d at the Ohio State University. The general meetings were held in the Botany-Zoology Building. This is the first meeting after the adoption of the new plan to meet in the spring.

THE LAKE LABORATORY. Plans for a successful session of the Lake Laboratory at Cedar Point next summer are rapidly maturing. It has been unofficially announced that a number of improvements to the building and to the sanitary arrangements will probably be made which will increase the efficiency of the laboratory and will also make for greater comfort in the living conditions.

The bulletin for 1916 has recently been issued. The session will begin on June 19 and will continue until July 28. As usual those desiring to spend a longer time at the laboratory are at liberty to do so. Director Osborn will be away on leave of absence this summer. The acting director will be Dr. F. H. Krecker of the Department of Zoology and Entomology at Ohio State University. Other changes on the staff include the appointment of Professor Schaffner of the Department of Botany at Ohio State University, and of Prof. Z. P. Metcalf, of North Carolina A. and M. College. Prof. Metcalf will conduct

the courses in Entomology and Ornithology. Among the changes to be noted in the curriculum is the increased attention which can be given to botany because of the presence of an additional botanist on the staff. Prof. Schaffner will have charge of Plant Ecology and Advanced Plant Morphology. Prof. Fullmer, of Baldwin-Walace, will direct the work in Systematic Botany and special work on the Algæ of the Cedar Point region. Dr. Krecker will enlarge the scope of the work offered in Aquatic Zoology which is presented from the ecological standpoint. Prof. Williams, of Miami University, will conduct the Advanced Invertebrate Morphology and the Vertebrate Anatomy.

In all the courses a special point is made of giving students as much contact with field conditions as possible. The Cedar Point region is fortunate in being one of the few inland points offering a wide range of conditions. The outdoor side of biological subjects is so important and is so slightly accessible to students during the winter that opportunities such as those offered at the Lake Laboratory are invaluable. It should be mentioned in this connection that the work done at the Laboratory is accepted for credit in most institutions. The facilities of the Laboratory are offered to both students and independent investigators and either Director Osborn or Acting Director Krecker will be glad to give information regarding necessary arrangements to any who may be interested. And of course early inquiries will be of advantage to everyone concerned.

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THE COMPARATIVE MORPHOLOGY OF THE ZOOCECIDIA OF CELTIS OCCIDENTALIS.*

BERTRAM W. WELLS.

The purpose of the present paper is three-fold:

1. To present a survey of the known insect and mite galls of Celtis occidentalis L.

2. To elucidate the histology of the normal gall bearing parts of the hackberry and that of the galls.

3. To study comparatively the structures treated, pointing out any significant conclusions and generalizations that may be attained in such a study.

During the course of personally collecting nearly five hundred types of zoocecidia, the author early discovered that the hackberry and its galls would afford a favorable combination with which to prosecute some anatomical work as outlined above. Four orders of cecidozoons are represented on this species of tree, causing seventeen known kinds of galls, of which sixteen are described in this paper. These orders do not include the hymenoptera whose galls are better known than those of the other orders. The histology of but one of the galls here presented, has been described previously. Since only one species of Celtis occurs in the regions (Ohio and Kansas) from which the material was obtained, no problems of correlation with various host plant species were encountered.

*Contribution from the Department of Botany, Ohio State University, No. 95. This paper is the partial fulfillment of the requirements for the degree of master of arts.

Neither Celtis occidentalis L. nor any of the known insects forming galls on it, are reported from Europe. Houard ([11], Vol. I, p. 367) mentions two mite and two aphid galls occurring on Celtis australis L. and one aphid gall on C. cretica L.

Most of the gall material and the pieces of the normal leaf and petiole were collected in the latter part of the summer to insure maturity, and were satisfactorily embedded in paraffine and aniline safranin and gentian violet were used in staining the serial sections. The one year old stem material was taken in mid-winter. The studies of the witches-broom, the psyllid stem galls, the lepidopterous stem gall and the structure of the normal stem were made from sliding microtome sections of alcohol hardened material. These were treated with iodine and mounted in glycerine, a method used by Brown and shown by him (not yet published) to give greater satisfaction in the case of woody structures, than the longer methods of embedding and staining. All drawings, histological in character, were made with the aid of a camera lucida or projection lantern.

About one-third of the work was done while the writer was on the teaching staff of the Botanical Department of the Kansas State Agricultural College, and he desires to express his appreciation of the kindly interest in the work on the part of Prof. H. F. Roberts and the other members of that department.

The remaining two-thirds of the work was completed in the Botanical Department of the Ohio State University under the direction of Prof. J. H. Schaffner, to whom the writer is indebted for many helpful suggestions, particularly in regard to the theoretical aspect of the subject.

It gives the author especial pleasure to acknowledge the very valuable assistance rendered by Mr. Forest B. H. Brown, of the Ohio State University botanical staff. His excellent grasp of plant anatomy has made possible a source of information and inspiration, upon which the writer has drawn heavily.

To Prof. Herbert Osborn, of the Ohio State University is due the hearty thanks of the writer for the loan of entomological literature.

Much work has been done on gall anatomy in Europe, but little as yet in America. The great majority of all the anatomical papers heretofore published have been general in character, dealing with many kinds of galls on many kinds of plants.

The present paper is perhaps unique in that it deals comparatively with practically all of the galls on one kind of plant, and with the normal tissues of that plant. The presentation of the histology of the normal plant parts will be given first.

HISTOLOGY OF THE NORMAL PLANT PARTS.

The discussion of the histology of the normal plant parts will be followed by the descriptions of the galls arranged under the proper insect order and family name.

The elucidation of the normal histology was deemed important, for it is necessary to have clearly in mind the results of normal differentiation to adequately understand to what extent the galls have deviated in their specific structure, from the normal plant characters.

The Leaf. (Pl. XII, Fig. C). The upper epidermal cells are comparatively large and bear externally a thick cutinous layer. Large cystolith cells (cys.) break the continuity of the typical epidermal elements. The expanded internal part of the cystolith shows the presence of the calcium carbonate in it by staining very lightly if at all, while the stalk and the round external knob takes the aniline safranin with avidity.

The palisade zone consists of two layers of cells, the inner being much less prominent and in places merging with the elements of the spongy layer so as to break its continuity. The spongy layer is relatively compact.

The fibro-vascular bundles possess a more or less definite bundle sheath, composed of highly elongated cells with evenly thickened walls. These are especially well developed above and below the bundle (Pl. XII, Fig. C, a). The xylem elements are the characteristic tortuous tracheides of the spiral type. The phloem cells are as in leaves generally of the thin-walled, more or less elongate, sub-cylindric form. The end walls often slant at an appreciable angle.

The under epidermis consists of cells somewhat smaller than those of the upper protective layer. The outer walls are sufficiently thin to permit the protoplasts to bulge them outward. The stomatal cells are minute, the pair being intercalated between the larger epidermal elements at their bases.

The Petiole. The petiole as seen in transverse section, shows the typical asymmetric orientation of the fibro-vascular bundles, which, taken collectively, form a crescent-shaped

area, lying nearer to the stem side of the petiole than the outer side. A segment from the middle of this region is shown in detail (Pl. XVI, Fig. D), extending from the epidermis on the side away from the stem axis, to a point on the inner side of one of the bundles.

The cortical cells and the epidermal cells show definitely thickened walls; a non-lignified type of thickening, however. These walls possess simple pits (not numerous). Scattered bast fibres are found in the inner cortical region, whose walls are not as thick, however, as those of the stem.

The phloem and xylem show no special characteristics. Tracheae and tracheids make up the body of the xylem, the tracheids being larger than many of those found in the stem and those found in the leaf.

The Stem. Figs A and B, Pl. XII, show the transverse and longitudinal, radial sections, respectively, of the one year old stem in winter condition. The cork layer is of the common type. The phelloderm is one cell layer thick. True collenchyma is but weakly developed, consisting when found in a favorable section, of but a single layer of cells of the outer cortex, with thicker walls than those beneath it. Since the cortex cells inward as far as the sclerid and crystal "sac" layer, have definitely thickened walls, the differentiation between them and the collenchyma is ill defined. These cellulose-thickened walls show minute inter-cellular spaces between, but the simple pits which doubtless are present in them could not be definitely demonstrated as were those of the petiole cortex.

On its inner side the zone of cells just described (primary cortex) is sharply delimited by a layer two or three cells thick (typically) containing two kinds of elements; sub-isodiametrical sclerides or stone cells and cuboidal to slightly tangentionally flattened cells, each containing a monoclinic crystal of calcium oxalate. See Figures labeled with abbreviations. This sclerid-containing cylinder of tissue is of especial interest because similar types of sclerenchymatous elements occur massed in various forms in most of the galls to be described hereafter. The region of the nodes, (particularly best developed in the cortex of the "angle") shows these two kinds of elements developed in sub-spherical masses.

The bast fibre cylinder is differentiated directly next to the layer just described. Within the bast fibre zone a layer of small celled parenchyma forms a transition tissue to the phloem which latter is typical and will not be discussed in detail, other than to state that the outer phloem parenchyma as well as that of the medullary rays in the phloem region, contain numerous sphaerraphides (calcium oxalate).

The cambium consists of the typical, tangentionally flattened brick-shaped cells, massed three to six cells deep before exhibiting differentiation.

In the xylem region wood fibres and tracheids of small diameter predominate. The tracheæ of both primary and secondary xylem are of the ordinary types. It might be noted in passing that the innermost tracheal element of the secondary xylem co-ordinates perfectly with the adjoining vessel of the primary xylem in the development of the transversely elongated bordered pits, which relate the two. The medullary ray cells in the region of the wood, shows the typical sclerenchymatized condition, with the walls containing numerous simple pits extending to the middle lamella.

The tracheids, whose distribution in the stem is variable are of particular interest in connection with this study, because of the fact that it is only this kind of xylem element which is found in the appendicular hemipterous and dipterous galls. In the stem they are of extremely fine structure, particularly those formed near the end of the season's growth, possessing spiral and split-spiral thickenings of very minute size.

Inwardly the primary xylem is bordered by some cylindrical elements with slightly thickened walls forming a transition tissue to the storage or "differentiated" pith, which forms the periphery of the medullary cylinder. The cells of this storage tissue possess as usual large numbers of simple pits.

The large celled pith is of interest, since an exactly similar type of parenchymatous tissue is found in many of the galls.

Older stems were examined showing the products of secondary growth, but nothing new or of a type which possessed additional significance relative to the problem in hand, was found. All of the galls on the hackberry are developed from the meristem functional in primary growth, the insects in all cases being unable to gain access to meristematic elements after the first cork layer has formed.

Callus was not grown and examined, since from much previous work it is evident that this type of homogeneous tissue, approximately the same for all plants, has no significance in relation to the gall problem.

Wound wood, however, was investigated, but nothing different was found from similar kinds of tissue reported in other trees. In none of the galls studied was anything found approximating in the slightest degree the condition of things characterizing wound wood. Such may be the case, however, as is shown by Stewart (31) in the gall of Andricus punctatus Bass. on the oak.

DESCRIPTION OF ZOOCECIDIA.

Thomas (32) has defined a gall as "a variation in the form of plants caused by a parasite." This definition, though rather widely accepted, is too indefinite and does not delimit certain irregular conditions in plants brought about through predaceous insects and intracellular fungi, conditions which are never associated with the word cecidium or gall. In the author's work on zoocecidia (nematode, mite and insect galls) he has found it possible to adhere to the following definition for zoocecidium: An hypertrophy (abnormal enlargement of single cells) or hyperplasia (abnormal proliferation of cells) of plant cells causally related to certain parasitic animals. Both hypertrophy and hyperplasia may go on in the same gall. The only cases which this definition does not cover are those in which the normal tissue suffers differentiation inhibition without evident hyperplasia or hypertrophy. These cases are extremely rare. The xylem region of gall 1, described in the present paper is an instance of this kind, but as the cortex suffers marked hyperplasia this case is not a true example. Cases of this sort in which the number and size of the elements is not increased, only their qualities have changed, are included by Küster (15) under "Metaplasias."

Küster (15, 16) in his Pathologische Pflanzenanatomie has given phytopathology an excellent classification of cecidia in general. All of the galls described in the present paper fall under his "Heteroplastic Tissues," that sub-division of hyperplasias which shows "definite quantitative increase of an organ, in which by abnormal cell division, tissues are produced, the single elements of which do not resemble normal ones.

If the tissue of the heteroplastically changed organs and parts of organs be compared with corresponding normal tissues, differences will be found in more than one connection; the abnormal tissues vary from normal ones in regard to size of the single elements, as well as to the degree and kind of differentiation."

In the mind of the writer, the "degree and kind of differentiation" of tissues is the most significant with particular reference to the form assumed by the heteroplastic tissues as opposed to the forms of similar tissues in the normal parts.

Heteroplasmas, Küster divides into two sub-divisions, "Kataplasmas (differentiation not widely different from the normal) and "Prosoplasmas" (differentiation definitely and specifically different from the normal). The acarinous and lepidopterous galls (one each) to be described hereafter fall under the first, while the hemipterous and dipterous forms are all excellent examples of the second.

In the description of the galls, the taxonomic characters will be presented first, followed by the discussion of the histology.

In conformance with a previous paper (Wells [33]) the new galls described are not named, but given a list number. As pointed out in that paper it is essentially unscientific to name an insect with only the gall at hand. No entomologist would feel justified in creating a species on the characters of a puparium or coccoon, for such a structure embraces but a small part of the total number of characters to be considered. Only the paleo-entomologist should have the privilege of dealing in fragments. While it can be shown that the specificity of the galls is related to the specificity of the adult insects, this relation is not a causal one, but is merely a relation established through the fact that both gall and adult insect have a common specific origin in the larva. If the entomologist is to properly describe his unit (species) he should have all of the differentiation products coming out at the end of the insect's ontogeny. Too frequently, the entomologist has ignored the gall as a "deformation," when it is often as specific as the antennæ in its form and structure characters.

KEY TO GALLS OF CELTIS OCCIDENTALIS.

1. Twig galls; twigs massed and showing enlargement of bases, witches broom. *Eriophyes* sp. (1).
1. Twig galls; aborted lateral twigs, isolated not aggregated, Lepidopterous gall, (2).
1. Twig galls; simple low, ovoid swellings on sides of twigs, *Pachypsylla* sp., (4).
1. Bud gall; an abnormal enlargement of bud, *Pachypsylla gemma*, (5).
1. Galls on leaves and twigs, if on latter very different from foregoing. 2.
2. Gall of petiole, pear-shaped, large, involving entire petiole, *Pachypsylla venusta*, (7).
2. Leaf gall, blister-like, projecting but slightly from either side of leaf, *Pachypsylla vesiculum*, (3).
2. Leaf and twig galls, projecting prominently; definite appendicular structures. 3.
3. Leaf blade only; definite concavity on side of blade opposite gall, *Pachypsylla mamma*, (6).
3. Leaf blade, petiole and twig galls, on blade never showing concavity on side opposite the gall; itonid galls. 4.
4. Galls definitely conic; body of gall contracted distally. 5.
4. Galls definitely obconic; body of gall contracted proximally. 8.
4. Galls definitely globular, *Cecidomyia* sp., (14.)
4. Galls otherwise. 9.
5. Galls with ends attenuate, 6.
5. Galls with ends truncate (small nipple in center) 7.
6. Galls small, 2–3 mm. long, base not prominently expanded, *Cecidomyia* sp., (11).
6. Galls larger, 3–5 mm. long, base prominently expanded, *Cecidomyia unguicola*, (8).
7. Galls coarsely pubescent; distal half rather sharply constricted from basal, *Cecidomyia* sp., (13).
7. Galls smooth; distal half not constricted from basal half; stoutly conic, *Cecidomyia* sp., (12).
7. Galls smooth, larval chamber falls from the socket-like base. *Cecidomyia* sp. (16).
8. Gall sub-balloon-shape; basal half definitely constricted from distal expanded half, coarsely pubescent, *Phytophaga celtiphyllia*, (9).
8. Gall top-shaped; basal half not definitely constricted from distal half, finely pubescent, *Phytophaga wellsi*, (10).
9. Gall greatly flattened with central nipple; more or less prominent vertical, peripheral ridges present. (See end of introduction to the descriptions of the Itonididæ galls).
9. Galls relatively large, with very prominent, vertical, wing-like ridges projecting from the body of the gall, *Cecidomyia* sp., (15).
9. Galls generally in masses, larval chamber eventually loosening and dropping from the basal parts, *Cecidomyia* sp., (16).

Fam. Eriophyidæ. (Ord. Acarinæ).

This family includes the vast majority of the gall-forming mites. The galls are of simple types, though exhibiting great diversity. Most of the mite cecidozoons affecting the American flora, are undescribed, a condition related to the fact of their minute size and soft body, characters which demand a special technique to handle them. The majority of gall makers are members of the genus Eriophyes.

1. **Eriophyes** sp. This gall, a typical witches-broom, (Pl. XIX, Fig. 1) represents a more or less serious disturbance

of growth at the nodes. An excessive number (2 or 3 generally) of abnormal (wood reduced, pith increased) branches are produced from the same bud, followed by the development of an indefinite number of buds, all closely sessile in a mass at the node between the "gall" branches (Pl. XIII, Fig. 1). The subsequent infection of the basal buds of the new branches, the buds nearest to the original node attacked, accounts in great part for the characteristic irregular massing of the branches. If a young "broom" be stripped of its bark, (Pl. XIII, Fig. 1a), this relation of the primary and secondary branches is made evident. Often, however, in later years, buds located at the base of the primary "gall" branches will develop a shoot. After a number of years the mass of branches becomes so large as to be very conspicuous and unsightly. The author has investigated new branches growing on old galls without finding any mites. It seems probable that the condition of things grows worse after the primary infection, whether or not the mites are present.

The gall proper is altogether confined to the nodes affected, in which region two prominent facts stand out in relation to the histology of the parts affected: (1) The bases of the gall branches have suffered an inhibition of their differentiation; (2) The cortex shows definite hyperplasia. These facts are shown in Pl. XIII, Fig. 1c, which illustrates the longitudinal section of the part indicated at c, in Fig. 1a, which is a longitudinal, median section through a primary "gall" branch and the normal twig, from which it has grown out. The condition of the xylem is an extreme case of differentiation interference. Note the medullary ray cells are not very unlike those bordering it, cells which should have become wood fibres and tracheids, but which remain iso-diametrical, possessing simple pits scattered in the somewhat thickened walls. The co-ordination of the tracheæ, which do form, with the cells adjoining them by means of bordered pits, is not interfered with (Pl. XIII, Fig. 1 d).

Different branch bases show a wide variation in the degree with which normal differentiation has been checked. The extreme cases are almost uniformly composed of iso-diametric, simple-pitted cells, the thickening of the cell walls characterizing the pith region with as much intensity as the xylem. The least affected cases will show numerous vessels and tracheids, but few

if any wood fibres. This variation is undoubtedly related to the degree of differentiation attained before the advent of the mites in the spring growth period.

The hyperplasia of the cortex of the branch base is a constant character. The stone cells are found aggregated into sub-spherical masses, a condition also true of the crystal bearing cells. These masses were much larger and more numerous than those found in the normal nodes, and often are found in juxtaposition (Pl. XIII, Fig. 1 c).

The cork developes a greater thickness than normally, but is not sharply defined from the primary cortical parenchyma. The elements of this latter tissue do not thicken their walls.

The above study is corroborative of Küster's (15) dictum that all witches-brooms, whether mite or fungus induced, exhibit an essentially undifferentiated condition.

Kellerman and Swingle (12, 13) have associated a fungus (Sphaerotheca phytoptophila Kell. and Sw.) with this gall. No mycelium was seen in the affected tissues; indeed none would be expected belonging to the fungus named, since its position among the Erysiphaceæ would indicate it to be wholly superficial, the haustoria only affecting epidermal cells. Other well known witches-brooms, particularly those of Europe, have been shown to be caused by mites only. One on Syringa is especially striking. See Abromeit (1). There can be no doubt that the kataplasma under discussion, is wholly induced through the agency of acarinous organisms.

Lepidoptera.

Practically all of the lepidopterous galls are of the stem kataplasma type. The larva works its way into the center of the stem and from that vantage point brings about important deviations from the normal sequence of events in the growth of the tissue. This is in marked contrast to the mite induced galls, for the mites occupy at first at least, an external position. Stem mite galls are known, however, which at length enclose the animals.

2. **Lepidopteron** (species undetermined). This gall, (Pl. XIX, Fig. 2) is an aborted shoot from a lateral bud, developing very rapidly in the early spring, reaching its full size (in Kansas) toward the end of April. $1\frac{1}{2}$ – 3 cm. long, 4 – 6 mm. wide. The nodes near the end of the gall bear small leaves which die

early. Affected stems either smooth or pubescent. The larva finishes feeding on the central part of the galled twig and leaves the structure during the early part of May. It always eats out a circular hole near the base to make its exit. (Pl. XIII, Fig. 2 a). The gall soon after turns brown and drops from the parent branch.

Patton (26) has described a "hollow, elongate, twig swelling" from which he states cecidomyidous flies emerged "about the middle of June." From his brief description it is impossible to state whether his gall is the same as the one here described. The flies noted might have been parasitic on the lepidopteron.

Riley reports a tortricid, Proteoteras æsculana Riley, occurring on the hackberry. No mention of any gall is made, however, in connection with this tree, other than that the larvæ were found "on short twigs." On the buckeye and maple it "bores in the terminal green twigs, producing a swelling or pseudo-gall." (See Am. Nat. cit. below). This may be the insect concerned in the production of the lepidopterous gall herewith described, but from this mere suggestion of its gall forming habit, it is impossible to be certain.

Riley, Trans. St. Louis Acad. 4:321-322. 1882.
Riley, Am. Nat. 16:913-914. 1882.
Riley, 5th Report U. S. Ent. Comm. p. 609. 1890.

When studied histologically this gall is seen to be an excellent type of kataplasma (Pl. XIII, Fig. 2d). Sections of the normal and galled twigs are contrasted in 2b and 2c. The normal stem has suffered serious inhibition of its differentiation associated with marked hyperplasia. The xylem consists of but few primary and secondary vessels. The cambium is practically obliterated in the general mass of parenchyma formed. The bast elements never attain their ordinary heavy walls. The layer of stone cells with its accompanying crystal bearing elements does not appear at all. This study was made from material which had already begun to die back at the distal end, so that the condition found is not any stage of incomplete normal differentiation.

Fam. Psyllidæ. (Ord. Hemiptera).

The psyllidæ among hemipterous gall makers take third place, the aphididæ and coccidæ surpassing them in number of genera and species. Küster (17) reports seven genera from Europe. There are three known in America, the genera Livia, Trioza and Pachypsylla, which latter is confined in its gall forming habits altogether to the hackberry.

Five psyllid galls belonging to the genus Pachypsylla are herewith presented. The author concurs with Crawford (4, p. 111) in his monograph of the Psyllidæ, when he asserts that the following species of Pachypsylla erected by Riley (28) in the Fifth Rep't of the U. S. Ent. Comm., viz.: P. astericus, umbilicus, pubescens, globulus and cucurbita and P. rohweri Ckll, are "only variations of the species of P. mama, since the insects are said to be similar and the differences in the galls are not great." These species evidently represent intermediate forms between P. mama Riley and P. vesiculum Riley, though they are much closer to the former than the latter. The writer has noted the wide variation obtaining among the P. mama forms. The above named species will not be included in this paper, since their validity is rightly doubted. There are three species known other than those whose galls are dealt with in this paper, viz.: P. dubia, pallida and inteneris, but no galls are described with them. They are all said to be closely related to P. gemma Riley and may ultimately prove to be varieties of that species.

In the following studies diagrammatic presentation is resorted to in the elucidation of entire gall sections. Lignified tissue entering into the formation of the protective layers is shown by cross-hatching; simple stippling indicates parenchyma and the vascular bundles are outlined. The portions of the sections furnishing the diagrams used in detailed studies are outlined on the diagram.

3. **Pachypsylla vesiculum** Riley. This, the simplest of the psyllid galls, is a small (2–3 mm. dia.) monothalamous "blister" gall of the intervenal tissue, commonly found close to the principal veins of the leaf. They are apt to occur in great numbers. More or less evenly convex above; a small, rounded central papilla can be determined below. The galls, both above and below, become lighter in color than the normal leaf, though very green when young. Easily evident from the latter part of May on through the summer.

Riley, 5th Report U. S. Ent. Comm. p. 618. 1890.

The section of the gall in its position near a principal vein, is shown in Pl. XIII, Fig. 3. The convex zones of sclerenchymatized cells are very definite, extending over either side of the chamber, forming the protective envelope; protective in the

sense that it has a real function in preserving the delicate nymph within from mechanical injury. At x, is observed the primary cone (now flattened) which grew up and around the young nymph and at y, the rounded papilla, which represents the original downward evagination, which lowered the larva to the center of the leaf, making possible the comparatively greater hyperplasia of the central mesophyll.

The histology of the left part of the section shown in the diagram is delineated in Pl. XIII, Fig. 3a. The epidermis is not widely aberrant from the normal, though the cystolith cell has been partially aborted, which was uniformly the case when these occurred over the affected mesophyll. The upper palisade layer has maintained its integrity and the lower part of the spongy layer, nearly so, for stomata are present leading into small air spaces. The central mesophyll has, it is evident, been the tissue concerned in developing the "blister." It is of some interest to note that the thickness of the blister has been attained, not by a striking difference in the number of cells, comparing the periphery with the tissue near the chamber, but by the increase in size of the hyperplasia cells, the number of cells at the periphery and near the chamber being approximately the same. The protective layer appears broken, though if the adjoining sections are taken into account, the layer is found to be continuous in the fashion of a sieve. The sharpness with which the lignified cells are delimited from the outermost layers on both sides of the leaf is a prominent fact. The smaller veins of the leaf which traverse the region affected show very little if any modification. They pass between the lower epidermis and the protective layer. They do not, however, develop sheath tissue on the upper side, the side next the sclerenchyma layer.

4. **Pachypsylla** sp. (gemma? See next). Pl. XIX, Fig. 3.

This gall is a lateral, oval swelling of the stem, generally found near or involving the nodal region. 5–7 mm. long, $2\frac{1}{2}$–$3\frac{1}{2}$ mm. wide. Color and surface texture that of the normal bark. Predominately monothalamous; confluent cases occur forming a two-chambered and even a three-chambered gall. Very common on the terminal twigs of the hackberry. Remnants of old galls can be made out on stems 5–10 years old.

The galls are commonly torn open by birds to obtain the soft insects within, which spend the winter in the galls. One of these nymphs is shown on the gall (Pl. XIX, Fig. 3).

It is not definitely known whether the imagoes from this gall and those from the next, P. gemma, are identical. The nymphs appear to be identical. The galls, however, are distinct, a difference, however, which may be referable to the plant part affected rather than to any specific behavior on the part of the insects respectively. This matter will be explained after P. gemma has been described.

This gall started in a similar manner to that of P. vesiculum, by the larva inducing a cone of tissue to grow over it, burying it in the superficial layer of the young stem. This minute cone early becomes obliterated.

A transverse section of the stem and its gall is shown in Pl. XIV, Fig. 4a. The influence of the insect in modifying the growth and differentiation of the embryonic cortical tissue, has extended nearly around the stem. The outer protective layer is much heavier and better defined than the inner. Two prominent elongate, thick plates of mechanical tissue extend from the broken inner sclerenchyma zone, outward toward the attenuate edges of the outer mechanical layer; a definite adaption to insure rigidity. The soft interior tissue bounding the larval chamber is made up of cambium-like parenchyma, the cells being very regularly oriented in radial rows. This constitutes the nutritive layer (Pl. XIV, Fig. 4c).

Fig. 4b shows in detail a part taken at b, Fig. 4a. The outermost sclerenchyma elements are true sclerides and have numerous crystal containing cells scattered among them. The cork enveloping the gall is normal, except that the number of cell layers is not as numerous as in the unaffected stem. The epidermis and often the hypodermal layer with it, is found broken and peeling off, while that on the stem opposite the gall is intact.

A much magnified detail (Fig. 4d) has been made from the region d in Fig. 4 a, Pl. XIV, to show the origin of the tissue which has formed the bulk of the gall. At this point of transition between the hyperplasia tissue and the normal, it is at once seen that the phellogen layer has furnished the meristematic tissue, which has been directed to such unusual development, for the new tissue is strikingly shown to be intercalated between

the cork proper and the phelloderm, which is but one cell thick. In the region beneath the larva, the cortical parenchyma has suffered some hyperplasia, but this is not at all comparable in quantity to that of the phellogen.

In the case of the mechanical, laterally diverging plates, mentioned above, it is a matter of some interest to note that the sclerenchymatization of the two types of cells involved is perfectly uniform or continuous. While the boundary between the new cambium-like tissue and the cortical tissue proper is very definite, based upon the shape of the cells, the wall thickening processes have gone on with an equal degree of intensity in both.

5. **Pachypsylla gemma** Riley. Pl. XIV, Fig. 5.

As indicated in the specific name of the insect, this is a gall of the bud. The bud incept suffers extreme modification in its development, an irregular sub-spherical structure being formed, containing from three to eight chambers (Pl. XIV, Fig. 5). When the chambers are numerous the structure takes on a nodular aspect. 3–5 mm. long, 4–5 mm. wide. In many specimens faint outlines are present, suggesting the normal scale structure, though in no case are free scales present. The color is lighter than that of the normal buds. Very common. A normal bud is shown in Fig. 5 c, Pl. XIV.

This gall differs from the preceding in that it is uniformly polythalamous and always projects from the stem as a definite (appendicular) modification of the bud. The protective layer does not occur immediately beneath a cork layer, but differentiates beneath a thick zone of tissue, which can be interpreted as the homolog of the outer bud scale. Fundamentally, however, the two galls are similar and they eventually may be shown to be caused by the same species of psyllid. They are here separated for the reason that no transition forms between them have been observed.

In the cross section of a gall (Pl. XIV, Fig. 5 a) a heavy zone of lignified tissue is found enveloping the nutritive tissue within. The inner walls of the chambers develop somewhat irregular plate-like masses of mechanical tissue to support them. In the detail drawing (Fig. 5 b), the outer zone of homogeneous tissue is interpreted as the homolog of a bud scale. The definite row of cells on its inner border (at x) suggests

epidermis. The stone-cell type of sclerenchyma forms an extremely rigid structure. The nutritive tissue does not exhibit the regular cambium-like formation as observed in the preceding gall, its elements assuming an irregular aspect; those on the inner side being tangentionally stretched. The reduced fibro-vascular bundles traverse the outer region of the nutritive layer.

6. **Pachypsylla mamma** Riley. (Pl. XIX, Fig. 9; Pl. XV, Fig. 6, 6 a).

A short, sub-cylindric gall on the under side of the leaf, 5–8 mm. high, $4\frac{1}{2}$–$5\frac{1}{2}$ mm. wide at base, almost uniformly arising near a principal vein. The distal end varies from a definitely smaller diameter than that at the base, to a noticeably larger diameter, in the first case the galls are sub-conic with rounded ends, in the second, sub-balloon-shape, with the ends more flattened. On the upper side of the leaf is a conspicuous circular depression or basin, in the center of which a minute conic papilla is evident. This papilla is part of the first gall tissue developed, being the cone which grew up around the larva in the process of embedding it in the leaf tissue. In color the galls are light green, varying to violet and purple tints. Most specimens show a definite bluish bloom. The adult galls are smooth, though when very young they are covered with an array of long acicular trichomes. The galls when fully mature show interiorly a dome-shaped cavity, which extends to the very base of the gall. This cavity is developed through the dehiscence of the middle tissue of the nutritive layer. A secondary chamber, variable in size, though much smaller, is found in the region beneath the papilla. It represents the failure of the tissue above the larva to grow completely together. The walls are firm and brittle. The insects leave the gall about the time of the first frost and as imagoes spend the winter concealed in the bark of the tree. The galls are more or less abundant on hackberry trees everywhere.

Riley, Johnson's Universal Encyclopedia, p. 425. 1877.
Riley, 5th Rept. U. S. Ent. Comm. p. 618-619. 1890.

This histology of this gall has been previously studied by Cook (2 [v. 3, p. 426]) and Cosens (3 [p. 308]). The chief difference between those studies and the author's is the fact that the material studied for the present paper, disclosed the presence of a fine canal leading in from the distal end of the

gall. This will be described in a succeeding paragraph. In the paper by Cook, the secondary chamber mentioned above was inadvertently regarded as the larval chamber.

The specimens from which serial sections were made for this study were not fully mature. The old mature galls are practically impossible to cut satisfactorily. Certain features such as the nature and development of the nutritive layer can be studied much better in a somewhat immature gall than in the old ones when that layer has been disrupted.

The gall comprises two epidermal layers, iso-diametrical parenchyma tissue, sclerenchyma (protective layer) which is particularly well developed near the dome-shaped nutritive layer forming the central region (Pl. XV, Fig. 6b).

Fig. 6d presents the details of the blind canal region outlined at d, Fig. 6b. The epidermal cells lining the canal are slightly smaller than those on the other parts of the gall. The cutin layer is continuous down the canal to its blind end at the innermost sclerenchyma zone. A group of sclerenchyma elements, relatively large and highly pitted, occur on the inner side of this zone, directly beneath the canal. Inwardly the nutritive tissue adjoining these elements is composed of exceptionally large cells which have stiffened their walls by criss-cross thickenings (Fig. 6h), a type of cell not uncommon in the larger elements of nutritive layers.

The cambium-like nutritive layer is detailed in Figs. 6c and 6e. The protective layer is well on its way in the lignification of the cell walls though it must be remembered the condition here illustrated is immature. In the fully mature galls, cells near the periphery of the cecidium become lignified and the inner cells shown in the figures finally attain walls of such thickness as to be classified as stone-cells.

The fibro-vascular bundles traverse the gall on the under side of the nutritive layer. On the side next to the nutritive layer the bundles commonly possess one layer of bundle sheath cells (Fig. 6e). The bundles collectively form a very coarse net-work over the under side of the cambium-like central tissue.

A detailed study of the cystoliths is shown at f and g, Fig. 6b, Pl. XV. These are illustrated in Figs. 6f and 6g, respectively. The one on the edge of the gall shows marked abortion, evidently possessing little calcium carbonate in its structure for it stained

heavily. The other cystolith just beyond the range of the gall was entirely normal, the expanded part infiltrated with calcium carbonate staining but slightly. Houard (10, [p. 109]) reports aborted cystoliths on the border of a dipterous gall on Ficus.

Among the largest cells found in any of the galls, were some of the parenchyma units in the old, fully mature galls (Pl. XV, Fig. 6i). Contrasting with these are the normal cells of the leaf mesophyll (Fig. 6k), those of the petiole before their walls are thickened (Fig. 6m), those of the pith (Fig. 6n). All were drawn to the same scale.

The excessive enlargement of the gall cells can only go on in those cells retaining thin walls. These cells, however, cannot enlarge on the sides joining the lignified ones, hence the expansion must be at the ends away from the sclerenchyma cells. This type of development gives a characteristic radiate structure to the parenchyma locally, where it surrounds isolated sclerides or scleride groups, a condition presenting a striking appearance in the section of the old galls.

The discovery of the central, extremely narrow pit or canal in the distal half of this gall, makes it possible to correlate it to such varietal forms as Riley's P. curcurbita, which is smaller and presents a prominent, wide, yet deep, apical pit. If P. curcurbita should ultimately be shown to be a distinct species, it would as such form a transition type between P. vesiculum and P. mamma, though it stands closer to the latter than the former. One P. mamma gall studied failed to exhibit the presence of the distal pit.

7. **Pachypsylla venusta** O. S.

This gall is a large, hard, asymmetrical, pear-shaped modification of the petiole, variable in size according to the number of chambers found in the gall; the chamber number being directly related to the number of insects concerned in the formation of one gall (Pl. XIX, Fig. 8; Pl. XVI, Fig. 7). 1–2½ cm. long, 8 mm.–18 mm. wide. Surface minutely roughened, destitute of hairs. Yellowish gray to brownish in color. At one side, near the distal end of the gall is always a prominent concavity which is apt to be bordered by the remnants of the leaf blade. Interiorly, radiating from a central core, the walls give rise to conic chambers (Pl. XVI, Fig. 7a). This core, however, is attached directly to the wall of the sunken area or

sinus, above mentioned. These chambers vary in number from 3 to 14. The radiating walls are very thin near the periphery where they join the hard outer shell. Fig. 7b shows the gall with the side removed. The chambers are nearly filled with a white, flocculent, waxen mass, a secretion of the nymphs. The pupæ all emerge through the thin wall of the sunken area in the fall, and after the last ecdysis the insects fly to the bark, where they spend the winter. These galls are not common, the writer's entire collection numbering but a half dozen. They have not been seen in Ohio.

Osten Sacken, B. Ent. Zeit. in Stettin. p. 422. 1861.

Before discussing the histology, it should be noted that this gall is formed in identically the same fashion as P. mamma, though there are many insects concerned in its development. Once the tiny cones of tissues, which are concerned in the embedding of all the psyllid larvæ in the petiole, have overtopped them, extensive hyperplasia takes place, this hyperplasia eventually forming the central core. The hyperplasia of the rest of the petiole (the peripheral portion) of course keeps pace with that just mentioned.

A transverse section of the gall is shown in Pl. XVI, Fig. 7c. At a, is indicated a part which is enlarged nearby. An outer and inner part of this has been drawn in detail in Figs. 7d and 7e. The first striking feature of the outer wall of the gall is that of the presence of a cork layer on it. Küster (16 [p.206]) points out that cork formation on galls is a rarity. No cork, of course is ever found on the normal petiole. The cortical parenchyma cells have not thickened their walls as those of the normal petiole do. An extremely heavy layer of stone cells is developed, but is not continuous; numerous strands of parenchyma tissue extend through it. The nutritive layer (Fig. 7e) consists of the same thin walled type of tissue seen in that of the other galls, but it does not possess, in the adult condition, the typical cambium-like structure. The fibro-vascular bundles located in the outer part of the nutritive layer are small and numerous (much more so than indicated in the diagram). No bundle sheath is developed.

The central core is composed of a homogeneous mass of very large sclerenchyma cells. One of these is figured, Fig. 7f. The simple pits in the wall extend as far as the middle lamella. Fibro-vascular tissue is entirely absent from the core, a fact

related to the origin of the structure, for the embryonic tissue concerned in its development never was related to the procambial strands, but was entirely new hyperplasia tissue. The pores leading from the chambers through the core are lined with short multi-cellular trichomes. (Fig. 7g).

Fam. ITONIDIDÆ (Ord. Diptera).

This family, formerly known as the Cecidomyiidæ, embraces a large assemblage of gall makers. In the vast majority of cases, the egg is deposited superficially on the very young plant parts. The gall does not begin development until the larva hatches out and places itself in intimate contact with the embryonic plant tissue. This is followed in the galls found on the hackberry, by an upward growth of the tissue about the larva. The tissue above the larva never completely grows together, leaving what is called in the present paper an "apical canal." This very common type of gall is called by Küster the "umwallungen" form, a word very satisfactorily expressing the real nature of the gall. This type of cecidium stands in marked contrast to that in which the larva sinks into a diverticulum or pouch, a kind found on the leaf blade only.

Of the nine galls set forth in this paper, only three have had the adult insects associated with them described and named. Patton (26) in order to illustrate a method of naming galls, gave specific names to a few of the following galls, which Riley (28) had described, but properly left unnamed. Riley did not have the adult insects and Patton did not see Riley's galls, so we have the interesting case of a gall insect being named without the writer having seen either the gall or the insect. These names of Patton's are omitted from the present paper.

The galls described for the first time in this paper, are given a list number, which can be referred to by the entomologist who finally describes the adult insect. The heretofore undescribed galls and those yet unnamed are placed provisionally under the old genus name Cecidomyia, which has long served as a "storage" place for itonid "insectæ imperfectæ".

All of the galls are not worked out to the same degree of detail since they are of fundamentally different structure. Two of the simpler forms, exhibiting contrasting specific characters, have been chosen to adequately present, by full treatment, the histology of the itonid types on the hackberry.

The author, at this point, wishes to express his deep appreciation of the kindness of Dr. E. P. Felt, State Entomologist of New York, the American authority on the Itonididæ, for many helpful suggestions pertaining to the identity of some of the gall forms herewith presented.

Riley (28) describes one gall which has not been collected by the writer. To give a character of completeness to the itonid list, his data on this form will be given.

"33. On the under side of the leaf, arising from the leaf ribs, occurring either singly or in smaller or larger groups. Gall rosette-shaped, resembling the seed capsule of certain Malvaceous plants of the genus Hibiscus, circular in outline, greatly flattened on top and here furnished with a short central spine or nipple (frequently broken off); sides sulcate, with from ten to twelve more or less marked furrows, and with the corresponding interstices convex. Surface of gall not shining, lighter or darker brown, speckled with small, irregular, blackish pustules, and sparsely beset with moderately long whitish hairs, which are easily abraded. Average height of gall, .75 mm.; diameter 2–3 mm. Cell oblong oval, enclosed by thick, woody side walls, but with a thin bottom, and at the roof (i. e. toward the upper side of the leaf) covered with a thin soft layer. The gall is at once recognizable from its shape, but might readily be mistaken for a Psyllid gall" Riley.

This gall is probably Cecidomyia "lituus" Walsh, which is given by Felt as a "yellowish, disk-shaped gall with acute apical cone on leaf." Walsh's name "lituus" should not be associated with any hackberry gall. In the citation below he gave this name to the grape gall now called C. viticola, and mentioned, merely, the presence of two "similar galls" on hackberry leaves.

Walsh, Am. Ent. 2:28. 1869.
Riley, 5th Rept. U. S. Ent. Comm. p. 613. 1890.
Felt, Jour. Econ. Ent. 4. 1911.

8. **Cecidomyia unguicola** Beut. (Pl. XVII, Figs. 8, 8a).

On leaf, under side, a, sharply pointed cone-shaped gall with flaring base. 3–5 mm. high, 2–3 mm. wide. Light green to yellow in color. Smooth, almost shining. Monothalamous, rarely, if ever confluent. Chamber sub-cylindric, with the distal half thinner walled than the proximal. The distal one-third or one-fourth of the gall is delimited proximally by the

sudden transition from delicate sub-hyaline tissue to opaque hard tissue. Sooner or later the tip breaks off at this point. Riley states that "while issuing the perfect insect pushes off the tip." This gall is the most common of all the itonid galls of the hackberry; a hundred may often be found upon a single leaf.

Riley, 5th Rept. U. S. Ent. Comm. Gall No. 34, p. 614. 1890.
Beutenmuller, Bull. Am. Mus. Nat. Hist. 23:388, Pl. 13, Fig. 9. 1907.

The entire longitudinal section of this gall is illustrated in detail in Pl. XVII, Fig. 8a. This figure and the next are slightly diagrammatic in that the fibro-vascular bundles, which traverse the gall longitudinally without branching, are shown continuous, when actually they would be broken in any one of the serial sections, due to the fact that they do not pass to the tip of the gall in one plane.

The epidermis is uniformly composed of simple tangentionally flattened cells. The nutritive and protective layers assume an elongate cup shape, whose base is surrounded by the parenchyma tissue, which gives the gall base its flaring aspect. The nutritive layer is very thin, seldom over three cells in thickness. Note the unbroken condition of its superficial cells. The larvæ in all of the galls of this type do not feed on the cell tissues, but on the food material which passes into the chamber through the cell walls. The protective layer is sharply delimited from the nutritive, a condition common to all of the itonid galls studied. On its outer side the protective layer is only sharply set apart from the parenchyma on the side toward the leaf.

The nature of the cells composing the protective layer is shown in Fig. 8d, a small group of cells at the proximal end of the layer. The walls contain innumerable simple narrow pits, which pass to the middle lamella. This latter structure is in all cases continuous between the cells. Crystal cells are found in abundance directly adjoining the lignified thick walled cells, a condition obtaining in the normal stem (Pl. XII, Fig. A). Figs. 8e and 8f show the sclerides of the 1 yr. and 3 yr. old stems respectively, and are drawn to the same scale as those from the gall. The great majority of the lignified cells of the galls are larger than any found in the stem or in the stone of the fruit.

The distal one-third of the gall is composed of rows of very thin walled cylindrical cells. Distally the inner superficial layer of these give rise to numerous coarse trichomes, which choke the apical canal leading to the larval chamber.

The fibro-vascular bundles are not as large in proportion to the rest of the tissues as the principal bundles of the leaf. Their number and distribution are shown in Fig. 8b. Basally they are related directly to the bundles of the leaf or as is often the case they form a "knot" in the median basal region, this "knot" being related to a number of leaf veins. Küstenmacher (14) finds a similar "knotted" condition of the bundles at the base of certain Rhodites galls. The xylem elements are fine spirally thickened tracheids. The phloem cells are simple elongate cells whose end walls slant at a more or less prominent angle. No bundle sheath tissue is evident; the proximity of the bundles to the rigid protective layer making possible their support without the normal mechanical tissue being present.

The normal leaf (Fig. 8a) is very little affected where the gall is attached to it. The epidermis with its cystoliths and two palisade layers, exhibits hypertrophy, but this not to a marked degree. It is evident that the primordium of the spongy layer has furnished the basis for the hyperplasia constituting the gall.

In the chamber region is shown the section of the larva.

9. **Phytophaga celtiphyllia** Felt. (?) Pl. XVIII, Figs. 9, 9a.

A sub-balloon-shaped gall occurring on the leaves (either side), petioles and stems. 4–8 mm. high, including the apical, variable, attentuate tip, which arises sharply from the distal end of the gall body. 4–5$^1_2$ mm. dia. through the broad distal half of the gall. The sides do not taper proximally in the typical balloon fashion, but show a definite constriction below the distal expanded portion. When isolated the galls show a perfect radially symmetric structure, but they are apt to be found in clusters, resulting in more or less loss of symmetry through mutual pressure. When on the leaves they generally are found on the upper side attached close to the principal veins. These galls retain their green color longer than any of the others; when full size in mid-summer, the content of chloroplasts in the superficial cell layers is so great as to make them

fully as green as the leaf. Coarsely pubescent. The chamber is constricted distally. Galls not uncommon in Kansas, but this form has not been seen in Ohio.

The writer is practically certain that this is the gall described by Pergande, whose notes are presented by Felt with the description of the above insect. Pergande states it to be a "very hard, obconic gall, the upper extremity produced as a long slender nipple; at the base five or six low ridges. The galls occur on the upper side of the leaf and drop when mature." Unfortunately no measurements are given. On the basis of the brief description, however, absolute certainty is not possible.

Felt, N. Y. State Mus. Bull. 180, p. 216. 1914.

The histology of this form, (Pl. XVIII, Fig. 9a), while fundamentally similar to that of C. unguicola, just described, presents many points which are of particular interest when contrasted with the features of the other gall.

A specimen on the leaf was chosen so that the two galls can be said to have a similar origin. The distal expanded or flaring portion of this gall (8) is seen to be due to the development of a mass of large celled parenchyma, comparable to that found in the proximal part of 7. The protective layer is thicker and divides distally so as to form a definite support for the mass of parenchyma just mentioned. The nutritive layer is extremely well developed; the thickest of any of the itonid galls. It will be noted that it is intact. The apical canal of the gall is not continuous into the chamber, the walls at its inner end having become tightly pressed together. The line between the two epidermises, however, was easily found in the serial sections used. The outer part, of definite diameter, is choked with slender trichomes, which are certain of the epidermal cells greatly elongated. The fibro-vascular bundles traverse the protective layer. Much more of the leaf is involved in this gall than in number 7 (Fig. 9a). In that portion of the leaf involved, the usual inhibition of the normal differentiation has ensued, the hyperplasia consisting of little more than a mass of parenchyma bearing greatly hypertrophied epidermal cells (gall trichomes) and the vascular tissue. As in all of these galls, no cystoliths or stomata ever were seen associated with the hyperplasia tissue. The longitudinal section of the larva is indicated in the chamber.

Fig. 9b shows the detail of the region indicated at Fig. 9a, b. The simple-pitted sclerenchyma cells differ only in the shape they have assumed on either side of the vascular bundle. On their outer side they are bordered by crystal "sacs," a relation which as observed earlier, obtains in the normal stem. More highly magnified sections of these cells are shown in Pl. XVII, Fig. 9c.

10. **Phytophaga wellsi** Felt. Cecidium nov. (Pl. XVII, Figs. 10, 10a).

On leaf, under side, more or less definitely obconic, resembling the shape of a somewhat flattened top. Generally found in clusters attached to the sides of the principal veins near the point of their divergence from the petiole. 2½–3 mm. high, 3–4 mm. wide. Distal end shows a more or less definite central prominence. Yellowish tinged, with short pubescence. Walls pithy in texture, yet firm; tissue when old, brown. Chamber sub-cylindric. Protective layer poorly developed, confined to proximal one-third of gall. Nutritive layer very thin. Fibro-vascular bundles traverse galls near the surface. This is the simplest of all the itonid galls studied.

Description of adult insect by Dr. E. P. Felt, in manuscript.

11. **Cecidomyia** sp. (Pl. XVII, Figs. 11, 11a).

On leaf, under side, a small (2–3 mm. long, 1–1½ mm. wide) sub-cylindric gall with attenuate tip, which is more or less definitely constricted from the body of the gall. Base rounded, light green to yellow, smooth. Thin walled, the chamber approximating the shape of the gall. The galls are commonly tilted over at a sharp angle, particularly when they arise from one of the larger veins. The protective and nutritive layers are distributed much as those of No. 7.

Riley first described this gall (No. 35 in his paper) and called attention to its similarity to C. unguicola Beut. (See No. 8). It differs constantly from that gall, however, in its smaller size and its non-flaring base.

Riley, 5th Rept. U. S. Ent. Comm. p. 614. 1890.

12. **Cecidomyia** sp. (Pl. XVII, Figs. 12, 12a).

"On leaf, under side, stoutly conical and nippled at tip. Succulent, pale green, and covered with fine bloom when young. 3x4 mm. Present in great numbers; larva, white." Sears.

The author's specimens rarely go over 3 mm. in high. They vary from 2–3 mm. in width. Many are purplish tinged. The chamber is sub-cylindric, rounded below.

The protective layer is well developed and extends distally as far as the inner opening of the apical canal. The nutritive layer is confined to the proximal half of the chamber wall. The fibro-vascular bundles pass upward close to the protective layer.

Sears, Ohio Nat. 15:384. Pl. 19, Fig. 33, 1914.

13. **Cecidomyia** sp. (Pl. XVII, Figs. 13, 13a).

"Leaf gall, present in great numbers on under side. A "peg-shaped" gall, cylindrical when young, and developing a thickened base as it grows. Pale green, straggling hirsute, 2–3 mm. long. Very common." Sears.

The broad, ill-defined ridges which characterize the base of this gall separates it from all others. The protective layer is relatively thick, but does not extend into the wall of the distal end. The nutritive layer is thin. The fibro-vascular bundles pass through the parenchyma basally but approach the protective layer apically.

Young specimens of this gall would closely approximate the gall described in Riley's report under No. 30. The expanded condition of the base is not gained until the gall has nearly completed its growth in length.

Riley, 5th Rept. U. S. Ent., Comm. p. 612. 1890.
Sears, Ohio Nat. 15:384. Pl. 19, Fig. 35. 1914.

14. **Cecidomyia** sp. (Pl. XVIII, Figs. 14, 14a).

A large, globular, mucronate tipped gall of the stem. 5–8 mm. dia. Base varies toward a truncate condition in some specimens. Green throughout the summer; finely pubescent. Chamber large, spherical. A thin membrane is constructed by the larva across the distal end of the chamber. Protective layer thick, nearly half as thick as the wall. Does not extend to apical canal. Nutritive layer relatively thin. The fibro-vascular bundles traverse the protective layer.

Riley describes a globular gall, which on "detaching the gall, the base is seen to be truncate and attached to the rib of the leaf by an extremely short, conical style, which is not visible from the sides. Average height, 3.5 mm., dia. at middle, 3.5–4 mm." See No. 32 in Riley's list. This gall

might be interpreted as an immature specimen of the above. Sear's number 34 is a variation of the above with the basal one-third developing low irregular ridges.

Riley, 5th Rept. U. S. Ent. Comm. p. 613. 1890.
Sears, Ohio Nat. 15:384, Pl. 19, Fig. 34. 1914.

15. **Cecidomyia** sp. (Pl. XVII, Figs. 15, 15a, 15b.)

This gall exhibits a remarkable variation from the previously described simpler types. Riley, who first described it, gave a very complete description of it, which will be quoted.

"31. Galls on the tender twigs, occurring either singly or in groups of two, three or four or more specimens; rarely also singly on the under side or even the upper side of the leaf. The gall bears a close resemblance to the winged seed capsule (achenium) of a Rumex, but the wings vary in number from three to five and are often irregularly developed, while the tip always ends in a curved, long spine. The wings terminate in a sharp ridge which is sometimes double. Gall opaque, not hairy. Color pale-yellowish green, at apical third usually of a more decided green and darker. A longitudinal section reveals a single large regularly ovoid cell surrounded by a thin hard wall. Average height of gall, 4.5 mm., excluding the apical spine; generally as wide as high; length of apical spine variable, but usually a little more than half the height of the gall." Riley.

The histology presents some points of special interest. The fibro-vascular bundles are found in the edge of the wings (Pl. XVII, Fig. 15b), from which branches are distributed inwardly to the protective layer. This is better shown in the longitudinal section, Fig. 15a. The protective layer is found, as in most of the preceding galls, to be confined to the proximal two-thirds or three-fourths of the chamber wall. Trichomes line the apical canal to the point where it opens in the chamber.

16. **Cecidomyia** sp. Cecidium nov. (Pl. XVIII, Figs. 6, pl. XIX; 16, 16a).

A gall of the leaves, stem, petiole or fruit occurring generally in an aggregate condition. An isolated specimen on the stem will be described to elucidate the fundamental unit characteristics (Pl. XVIII, Figs. 16, 16a). When found singly, the gall is irregularly conic or sub-cylindric, with a very blunt truncate tip. The chief character is involved in the fact that the gall

eventually drops its larval chamber enclosed by the nutritive and protective layers. This central part of the gall which slips out has the shape of a short, blunt horn. The tapering of this structure toward the proximal part of the gall makes possible the easy departure of this larva containing portion when the dehiscence layer surrounding it gives way. The gall aggregates commonly occur at or near the end of the stem, the tissue, after the larval chambers have fallen, dying, turning black, giving the twig an unsightly appearance (Pl. XIX, Fig.6). In the case of a single gall (Pl. XIX, Fig. 4) the stem is not killed, but the tissue of the "socket" part is cut off by an abscission layer (Fig. 16a, Pl. XVIII).

The gall on the fruit (Pl. XIX, Fig. 8) possesses exactly the same structure as those on other parts of the plant. The galls shown are not mature, the chamber not having burst through the surrounding supporting tissue. In section (Pl. XIX Fig. 4) the galls are seen to project into the ovulary cavity, exhibiting in their entirety the characteristic shape observed in those of the leaf which project from both sides of the leaf. The ovule is aborted.

The most important histological feature is naturally associated with the chief feature of the gall and consists of the dehiscence layer developed around the protective layer. This layer (Pl. XVIII, Fig. 16a) is made up of extremely thin walled cells, arranged in rows, radiating from the protective layer. It gives evidence of having been formed by rapid division when the gall was nearing maturity and becomes intercalated between the fibro-vascular system and the protective layer. Its eventual disintegration separates it cleanly from the protective layer, leaving the central part containing the larva free to be shaken out by the wind.

A few similar types of galls are known among the Cynipidæ and Itonididæ. Houard (11) figures an itonid (Oligotrophus Reaumurianus Loew) which is exactly similar. It occurs on Tilia grandifolia of Europe.

Comparative Studies.

Kataplasmas.

The two kataplasmas (galls 1 and 2) possess differences related in part to the position of the parasites on the stem. The excessive hyperplasia of the cortex, in the case of the witches-broom branch bases, seems to be associated with the superficial

position of the mites, while in the case of the lepidopterous gall the greatest hyperplasia is that of the pith, the medullary rays and cambium region, a condition correlated with the internal position of the larva.

Suppression of normal differentiation characterizes both. The lepidopterous gall partially developes bast, but no sclerides appear. The mite gall exhibits sclerides, but no bast. No lignification of the undifferentiated xylem cells occurs in the lepidopterous gall, but is very definitely found in the acarinous cecidium.

Compared with the normal stem, the most significant single fact concerning the kataplasmas, is the marked inhibition of differentiation with no substitution of entirely new tissue forms.

Prosoplasmas. Hemipterous galls.

Pachypsylla vesiculum (gall 3 and Fig. 3) is the simplest of the psyllid galls. Compared with the normal leaf it would appear that the middle cells of the immature mesophyll are most susceptible to the influence of the nymph, since these cells have carried out the hyperplasia.

The other four galls are all fundamentally identical in structure and mode of development with that of P. vesiculum. Gall 4 is the abnormally differentiated bud primordium. Gall. 5, (P. gemma) has developed for the most part from the stem phellogen, a tissue in the young stem undoubtedly more susceptible to control than that of the cortex. Gall. 6 (P. mamma) involves all of the leaf tissues, so that the gall can be considered as a mass of "new" tissue intercalated in the leaf blade, but suspended below the leaf blade plane. Gall 7 (P. venusta) illustrates the same mode of development seen in No. 6, carried out on the petiole by a number of larvæ rather than one. (See description under 7).

It can be said that the above psyllid galls, characterized by little or no "umwallungen" development with rather ill-defined protective layers surrounding nutritive tissue possessing a cambium-like structure, constitute a generic type of gall for the hackberry, a type which contrasts strikingly with the generic type of itonid galls.

It is of course evident that the specificity of the different galls is in part due to the instinctive behavior of the insects in choosing particular plant parts. This is strikingly shown by comparing P. mamma with the gall on the side of stem (No. 4).

The evagination beneath the larva so prominent in the case of P. mamma could not, naturally be carried out on the stem, hence the hyperplasia in that case is almost entirely lateral to the insect and above it. Discounting the factor of the plant part selected there is the quantitative evidence indicating specificity in the intensity of the stimulus which developes the generic type of gall.

Compared with the normal tissues these galls show the abortion or complete absence of certain normal specialized cells, such as stomata, cystoliths, tracheæ, bast, wood fibres and sieve tubes.

Prosoplasmas. Dipterous galls. (Itonididæ).

Galls of Cecidomyia unguicola (8) and Phytophaga celtiphylla (9) were chosen to illustrate in detail the definite specificity which characterizes these highly evolved forms of prosoplasmas, which are induced by the insect larva to grow upon the same leaf. This fact of the gall species being definitely and constantly related to the insect species, is a fact of far reaching significance. It has long been known among European workers and Cook (2) on a histological basis, first called attention to it in America.

In the case of these two galls some of the contrasting characters are: Notable difference in size (they are drawn to same scale). In 8 the proximal development of large celled parenchyma, opposed to its distal development in 9. Much thicker protective and nutritive layers in 9 than in 8; shape of layers also different. Apical canal tightly closed proximally in 9, open throughout in 8. Trichomes in apical canal of 9 smaller than those in canal of 8. Large acicular trichomes developing over surface of 9, while 8 is always perfectly smooth. Hyperplasia of leaf at base of gall, extends much farther in 9 than 8.

Comparing the other itonid galls in a similar manner will yield just as striking results. In the following discussion of the remainder of the galls, only the more significant specific characters will be emphasized.

Phytophaga wellsi (10) is the least specialized. Its protective layer merging insensibly into the distal parenchyma and its simple closed apical canal are the two most important characters placing it below the others in the degree of complexity attained.

No. 11 is similar to 8, but simpler. It is constantly smaller and does not develope the expanded base, so characteristic of 8.

The extension of the protective layer to the apical canal is found in No. 12 only.

In No. 13, the epidermis lining the chamber at the apical end of the gall is composed of perpendicularly elongated cells which are filled with a fine granular substance (Fig. 13b, at x, pl. XVII), the nature of which was not determined. The character was constant, being exhibited in many galls examined. Such a cell layer was not observed in any other itonid gall.

No. 14 has the fibro-vascular bundles traversing its sharply defined protective layer. In this respect it is similar to 9. These two galls differ from all the others, having definite protective layers, in this character. Küstenmacher (14) has noted the diversity in Rhodites galls in this regard.

The alate condition of 15 makes it an object instantly indentifiable. With this character is associated the peculiar distribution of the bundles (Fig. 15a, pl. XVII), not found in any other gall.

No. 16 possesses many characters setting it apart from the others, the most important of which is the development of the dehiscence layer in it, permitting the larval chamber to drop out. Nothing in any of the other galls is directly comparable to it.

All of the hackberry itonid galls are of the "umwallungen" generic type. The kinds of cells found in the galls are not widely dissimilar, the specific characters being confined to the kinds of tissues, with particular reference to the form the tissues assume.

There is a character which the writer desires to point out, which is found not only on most of the itonid galls of the hackberry, but on those of other plants, the significance of which has not been determined so far as the author is aware. The protective layer in most of these galls is sharply delimited apically giving rise to a distal segment of the gall composed wholly of parenchyma (No. 12 excepted) a segment which is evident in many galls upon superficial examination.

It is proposed to call this segment the "apical segment," though the writer has not used this terminology in the present paper because of the uncertainty as to its value in taxonomic description. No ontogenetical studies of this type of gall have as yet been made by the writer to demonstrate if this apical segment bears any relation to the minute cone which early developes over the newly hatched larva.

In way of summary it can be stated that the hackberry itonid galls exhibit in an especially strong fashion, specificity, based upon the generic "umwallungen" type of cecidium. This specificity is directly related to the specific physiological phenomena of the larva and holds, whether the gall appears on the young tissues of the leaf, petiole, stem or fruit. The insects commonly, however, tend to oviposit on a particular plant part, (this probably being the most important factor in determining the position the larva eventually takes), and the galls thus become associated with that part. But as in the case of 16, it is seen that the character of the gall's position on the plant would be of no taxonomic value whatever, since these galls have developed from the young tissue of leaf, petiole, stem and fruit. Many of the others have been reported from more than one plant part.

The comparison of the two generic types of prosoplasmatic galls will yield some interesting data.

Of the psyllid galls Pachypsylla mamma (6) shows best the generic type to which it belongs. Occurring on the leaf it can be contrasted to advantage with the numerous itonid leaf galls. Given the P. mamma larva and an itonid larva (one like Nos. 9 or 13, which commonly form galls on the upper side) on the same young leaf, on the upper side there will occur an entirely different series of changes as evidenced in the final stages, the mature galls. In the case of the psyllid the minute "cover" cone which grows up around the larva, remains small, the gall being composed almost wholly of hyperplasia tissue beneath and to the sides of the larva. The larva is lowered, as it were, in a downward evagination, the sides of which growing inward above eventually developing a thick wall over the larva. The primal "cover" cone does not contribute to this, but remains small and can always be seen in the center of the upper concave side of the gall as a minute papilla.

In the itonid gall very little hyperplasia takes place beneath the larva, the gall being developed from the primal "cover" cone, the gall becoming an appendicular structure on the upper side of the leaf, while in the psyllid it is on the under. Most of the itonid larvæ begin operations on the under side of the leaf, resulting in the gall having that position, but this does not destroy the significance of the fundamental difference between the two types of galls.

Histologically the itonid galls show a much higher condition in the definiteness with which the nutritive, protective and parenchyma tissues are distributed. Also, greater diversity of specific characters is introduced by the larvæ, in itonids than in psyllids for in the latter a definite part of the form character is related to the kind of plant part on which the gall is developed. In the itonids the form character is wholly related to the larva.

Comparing the prosoplasmas with the normal tissues it is strikingly evident that we have, as many European cecidologists have pointed out, entirely new structures. This "newness," however, in the hackberry prosoplasmas, consists of new forms, assumed by tissues, which are composed of cells that have close if not identical counterparts in the normal parts. Commonly the parenchyma and sclerenchyma elements of the gall tissues are much larger than those found in the unaffected structures, but in no case can it be said that the cells of the galls are fundamentally different from those observable in the normal plant.

Heteroplasmas, (All of the galls).

In comparing the kataplasmas with the prosoplasmas, it can be inferred that the amount of embryonic tissue influenced in the beginning stages of the gall is greater in the former than in the latter. In the case of the lepidopterous gall the fact of the greater range of the stimulus is doubtless associated with the relatively greater size of the larva; in the mite gall, to the numerous individuals present at a particular point of attack. In both cases this condition is enhanced by the migration of the arthropods from one part of the affected region to another, a phenomenon known to take place in these galls, but which is not true of the prosoplasmas. In these the larva is quiescent, while the definite new form of tissue is growing about it. This has been demonstrated by the writer in P. mamma and by Fockeu in dipterous galls. The low type of heteroplasia (kataplasma) relatively undifferentiated, and the highly differentiated form (prosoplasma) undoubtedly owe their difference in great part to the distinction in the arthropods just pointed out.

It should be noted that the difference between kataplasmas and prosoplasmas is not a difference in kind, but a difference in degree only, as Küster (15) pointed out when first presenting this terminology.

The xylem of the kataplasmas showed the presence of subnormal tracheæ, while that of the prosoplasmas, even though occurring on vessel bearing parts, always possessed narrow, elongate, spirally thickened tracheids only.

All of the galls when compared with normal parts show partial or total suppression of normal tissue characters and the substitution of new characters. The new characters, no matter whether little or greatly divergent from the normal, are specifically related to the arthropod concerned in calling them forth.

In all of the galls, except the lepidopterous one (2), lignification of certain parenchyma elements has taken place, giving rise to more or less definite sclerenchyma tissue forms (protective layers), which in no case finds a counterpart in the normal plant. This layer doubtless is definitely functional in preventing mechanical injury to the larva.

General Considerations.

This paper does not deal directly with the etiological problem, the greatest problem in cecidology, but does deal with it indirectly in attempting to make clearly evident, the phenomena appearing at the end of certain gall ontogenies; the phenomena to be explained (it is hoped) through etiological investigations. At this point it might be well to state (for it is a fact not generally known) that the nature of the stimulus applied by the insect is not known. Magnus (20), whose recent work presents an excellent summary of the etiological problem, closes with this sentence: "Der hypothesen sind genug gewechselt, lasst uns auch endlich Tatsachen sehen." All the evidence arising out of experimental studies of the problem point toward a chemical interpretation (enzymes, etc., secreted by the larva), but as Küster (17) repeatedly has pointed out, the experimental evidence definitely supporting any chemical interpretation does not yet exist. In the true scientific spirit he acknowledges the chemical theory to be, as yet, a necessary inference only.

From the preceding comparative studies, particularly those of the prosoplasmas, it is clearly evident that the gall represents something new as far as the *form* content of the tissues and their particular orientation is concerned. The particular combination of sclerenchyma form, parenchyma form, and

bundle tissue, observable in any of the prosoplasmas, does not even find an analogy in the normal structure. The cells of the galls, however, all have their homologs in the normal tissues. Cosens (3) states: "The conventional view to account for these phenomena is that the protoplasm has been endowed with entirely new characteristics and power to produce something foreign to the normal host. But this probably is true only in a very limited sense for according to my experience at least the prototypes of such apparently new tissues, etc., have been found elsewhere in the host or its relatives." He bases this statement on a comparative study of special structures, such as "glands, trichomes and aeriferous tissue," which reappear in certain galls in *addition* to the definitely new tissue "forms," constituting the gall as a whole. Any comparative studies of cecidia and normal parts should take into consideration the whole structure and when this is done the essential "newness" of the cecidium appears.

In the form characters of the gall tissues (gained through growth, i. e., proliferation and differentiation of cells) we have characters, which without any doubt whatever, are ascribable to the specific physiological phenomena of the insect. In other words the insect larva controls the growth of the embryonic tissue in its immediate vicinity, this growth developing a new structure, showing specific characters as definite and constant as the group of characters observable in the adult insects. A glance at plates 6 and 7, showing nine species of itonid galls, all but one of which have been seen by the author, on Celtis leaves, will demonstrate to any one the validity of the above statement.

An analysis of form character can be made, which will disclose certain factors over which the insect has undoubted control.

Form character with respect to tissues in the normal plant is directly related to the orientation of the mitotic spindle axes and the number of divisions during growth, and the sizes attained by the cells after mitotic activity has ceased. These factors are of course influenced by the ever present factor of environment. To the growth factors should be added the factor (the nature of which is unknown) which directs differentiation. In the gall problem this is particularly involved in the appearance of the lignified sclerenchyma tissue (protective

layer), which in all cases represents a zone of parenchyma cells, which change their activity from growth to thickening of their walls.

In the case of the development of a number of species of galls on a particular leaf, the physical environmental factor can be thrown out, since it is the same for all. It is the biological environmental factor (the larva) which is now the external factor controlling the internal ones operative in developing tissues. These internal ones, to state them again are: The factor or factors related to the orientation of mitotic spindle axes and the number of mitoses carried out; the sizes attained by cells after mitotic activity has ceased; the factor or factors directing the distribution of differentiation products, which in this morphological study has particular reference to the thickening (lignification) of walls. Any theory concerning the nature of the stimulus should adequately explain how the particular stimulus exercises its control over the above factors, which factors, be it noted, are the most important factors entering into the growth of tissues.

It should be noted in the above analysis care has been taken to definitely distinguish between the factors related to the development of particular kinds of tissues and those related to the development of particular kinds of cells. These distinctly intra-cellular factors making possible mitosis, growth in size of cell, lignification of cell wall and the like, it would appear are practically undisturbed, for from the standpoint of the cells there is little or no fundamental difference between those simpler ones in host tissue and those in the galls. It should be remembered, however, in this connection, that highly specialized cells, such as cystoliths, etc., do not appear in galls.

Before leaving this phase of the subject, attention should be called to the fact that much evidence exists to show that these fundamentally new gall tissues are carrying out fundamentally new functions. This material, however, would be out of place in a paper intended to be purely morphological.

Material of some interest may be forthcoming if we view the above conclusions in the light of modern genetic conceptions.

Cosens (3) states, "this much is certain that there appears to be an entire lack of evidence supporting the view that the protoplasm of the host has become endowed with a property that enables it to produce a fairly definitely shaped but withal

abnormal structure. Such a pronounced change would surely be expressed in the heredity characteristics, yet there is not a vestige of proof tending to show that insect galls ever produce the slightest variation in the descendants of the host." The "protoplasm" referred to above is the germ plasm and, used in this sense the statement made, is correct. While nothing is known concerning the difference in the meristematic tissues of gall bearing plants as opposed to non-gall bearing forms, there is no reason for hypothesizing a special constitution for the germ plasm of the gall bearing flora. Nearly all of the orders of the Anthophyta possess gall bearing plants.

On the contrary, morphogenetical studies constantly and definitely point to the germ plasm of the insect as the place of origin of gall forms. These gall forms (tissue forms taken collectively) are almost without exception found to be specifically related to the insects associated with them, this being exhibited in the most striking manner in all of the higher prosoplasmas. In the prosoplasmas it can, with certainty, be said that we have the remarkable and unique case of the overlapping, as it were, of an animal hereditary constitution on that of a plant; a situation in which the plant's tissue "forming" factors (not tissue growing factors) are suppressed and new ones substituted. In this connection it should be remembered that in the early stages of all prosoplasma ontogenies, the larval insect is in contact with the undifferentiated plant tissue; a contact as intimate as that between one part of a growing plant and an adjoining part. Fockeu (6) correctly states that the early phenomena observed in the reaction of the plant part is "en rapport" with the "phenomenes vitaux" of the gall inducing form.

Since science knows little or nothing concerning the mechanism by which hereditary factors are enabled to come to expression in form and otherwise, it is suggested that in the zoocecidological field, we have a unique place to attack this problem. Hybridization of gall insects to see if the F_1 and succeeding generations of galls would follow known hereditary laws, undoubtedly would prove an extremely suggestive line of investigation. But the great discovery which will undoubtedly go far toward helping us understand the mechanism of heredity will be that of the exact nature of the stimulus involved in producing these problematic plant tissue **forms,** comprising the prosoplasmatic zoocecidia.

SUMMARY.

1. There are seventeen known species of zoocecidia occurring on Celtis occidentalis, belonging to four orders of arthropods: Acarinæ 1, Lepidoptera 1, Hemiptera 5, Diptera 10. All are heteroplasias, i. e., those forms of hyperplasias (abnormal increase in size through cell proliferation) whose cells and tissues differ from the normal. All, be it noted, are built up on the basis of the same germ plasm, viz., that of the single species of the plant mentioned.

2. The acarinous and lepidopterous galls are kataplasmas, or those forms of heteroplasias whose cells and tissues do not vary widely from the normal. Each shows specific and characteristic inhibition of differentiation.

3. The hemipterous and dipterous galls are prosoplasmas or those forms of heteroplasias whose cells and particularly whose tissue forms differ fundamentally from those of the normal parts. Each of these galls shows definite specificity. In the hemipterous forms the specific characters are in part related to the plant structure which bears the gall; in the dipterous galls the specific characters are wholly related to the specificity of the physiological phenomena associated with the species of larvæ concerned in the development of the galls.

4. In the prosoplasmas the types of cells found are closely comparable to those of the normal plant parts, but the tissue **forms** discovered are fundamentally new; no analogous structure forms are to be found in the tissues of the normal plant or its allies.

5. In the dipterous prosoplasmas, since the gall's specific tissue **form** characters are related to the species of insect, we have the unique case of the "overlapping" of the hereditary constitution of an animal on that of a plant in the sense that factors associated with the insect determine the form character locally, rather than those normally associated with the plant's germ plasm. These latter plant factors suffer suppression.

6. It is suggested that in the field of zoocecidology we probably have a unique place, heretofore unrecognized, to attack the problem pertaining to the mechanism used in the expression of hereditary characters.

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EXPLANATION OF PLATES.

(See also table of abbreviations following.)

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Fig. A. Cross section of normal one year old stem of Celtis occidentalis in winter condition. × 170.
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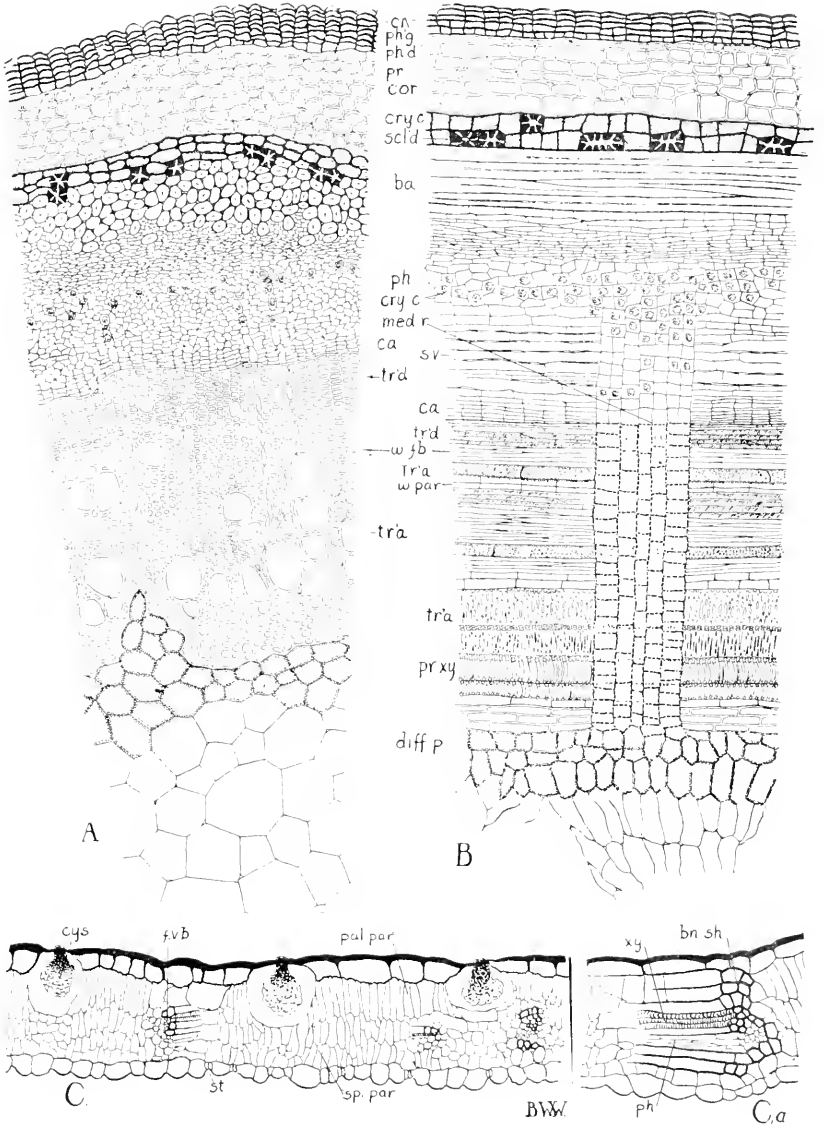
TABLE OF ABBREVIATIONS.

abc. l.—abscission layer.
ab. xy.—abnormal xylem.
ab't. cys.—aborted cystolith.
ap. c. tr'm.—apical canal trichomes.
ba.—bast.
bn. sh.—bundle sheath.
ca.—cambium.
ck.—cork.
cor.—cortex.
cor. par.—cortical parenchyma.
cys.—cystolith.
cry. s.—crystal "sac."
cu.—cutin.
deh. l.—dehiscence layer.
diff. p.—differentiated pith.
epi.—epidermis.
g. cor.—gall cortex.
hyp'l. mes.—hyperplasied mesophyll.
hyp'l. ph'g.—hyperplasied phellogen.
hyp't. pal.—hypertrophied palisade tissue.
la.—larva.
l. c.—larval chamber.
l. v.—leaf vein.
lig. scl.—lignified sclerenchyma.
med. r.—medullary ray.
m. la.—middle lamella.
nut. l.—nutritive layer.
nym.—nymph.
p.—pith.
pal. par.—palisade parenchyma.
ph.—phloem.
ph'd.—phelloderm.
ph'g.—phellogen.
pr. xy.—primary xylem.
pro. l.—protective layer.
scl'd—scleride.
scl'd. l.—scleride layer.
sim. p.—simple pit.
sp. par.—spongy parenchyma.
s. v.—sieve vessel.
tr'a.—trachea.
tr'd.—tracheid.
w. par.—wood parenchyma.
xy.—xylem.



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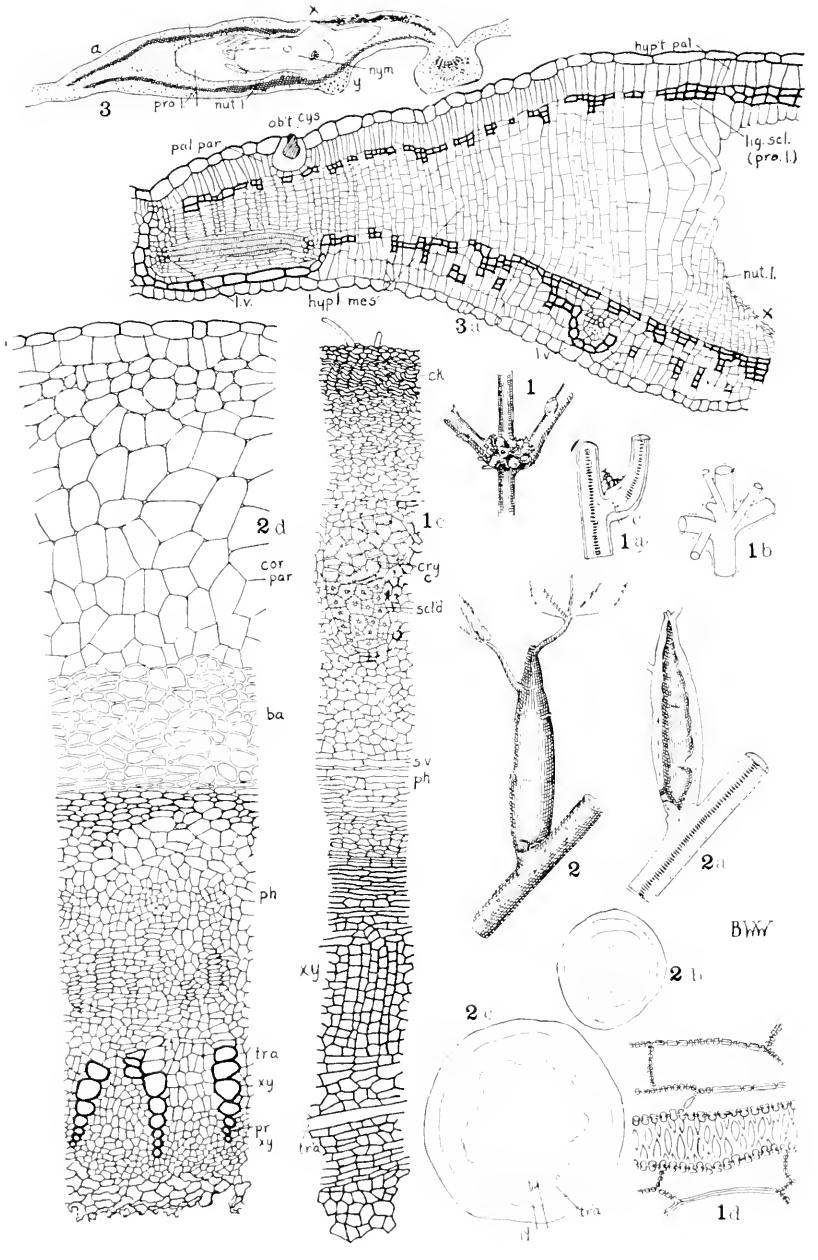

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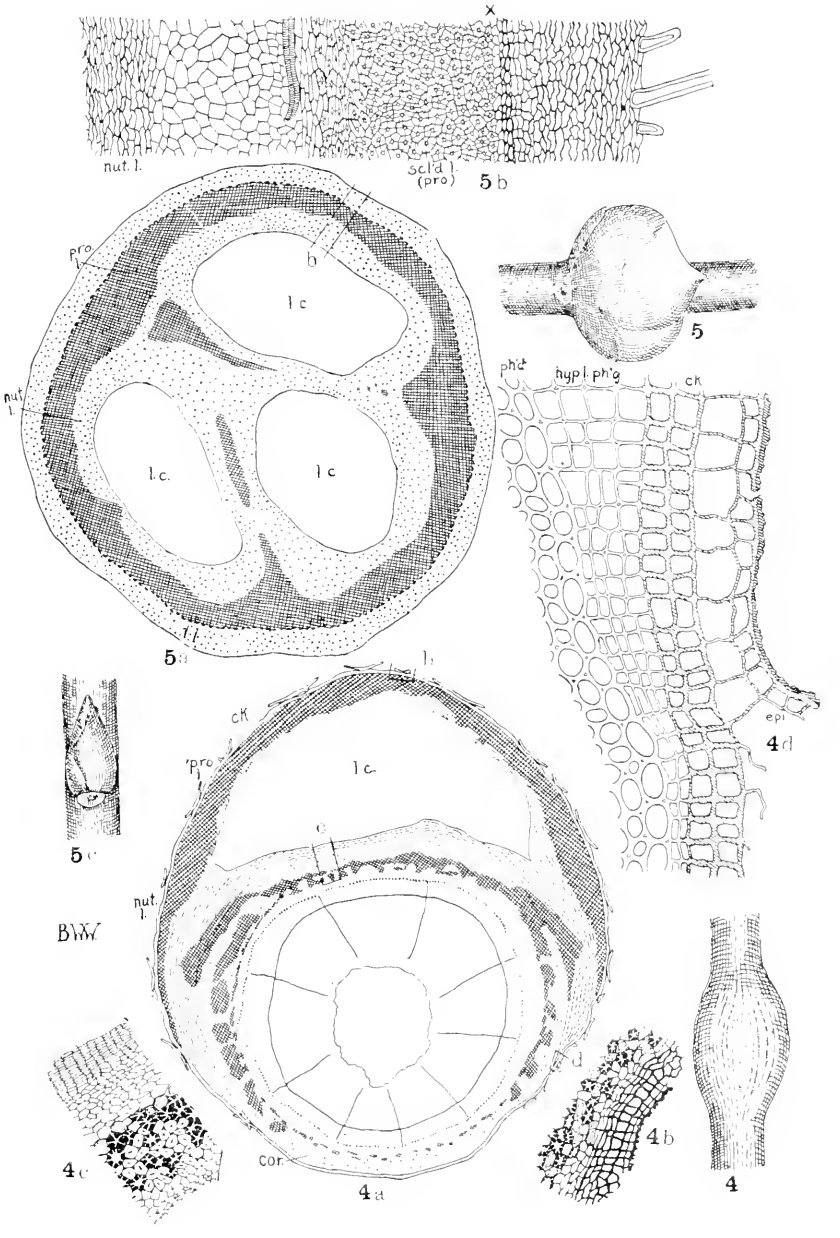

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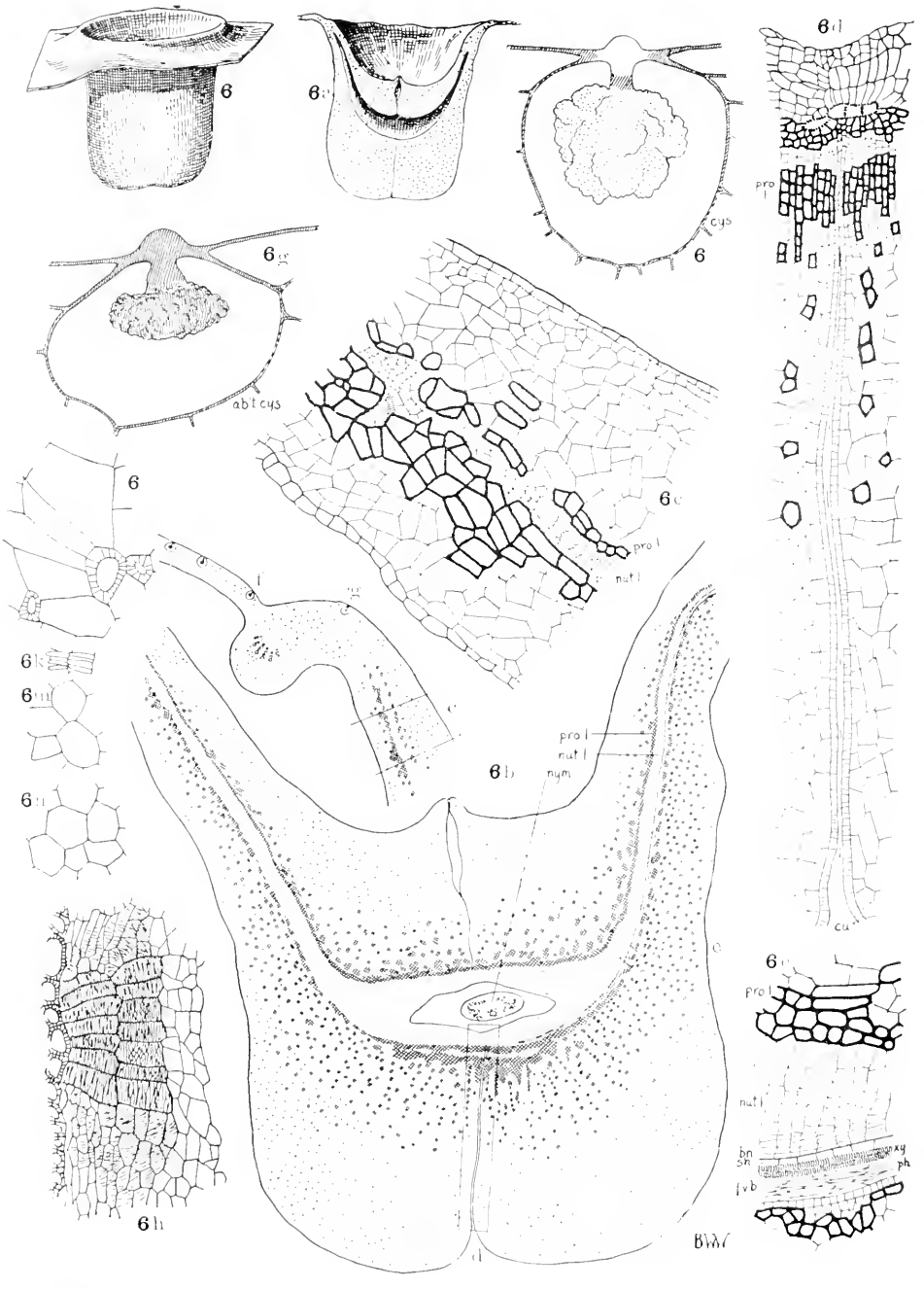

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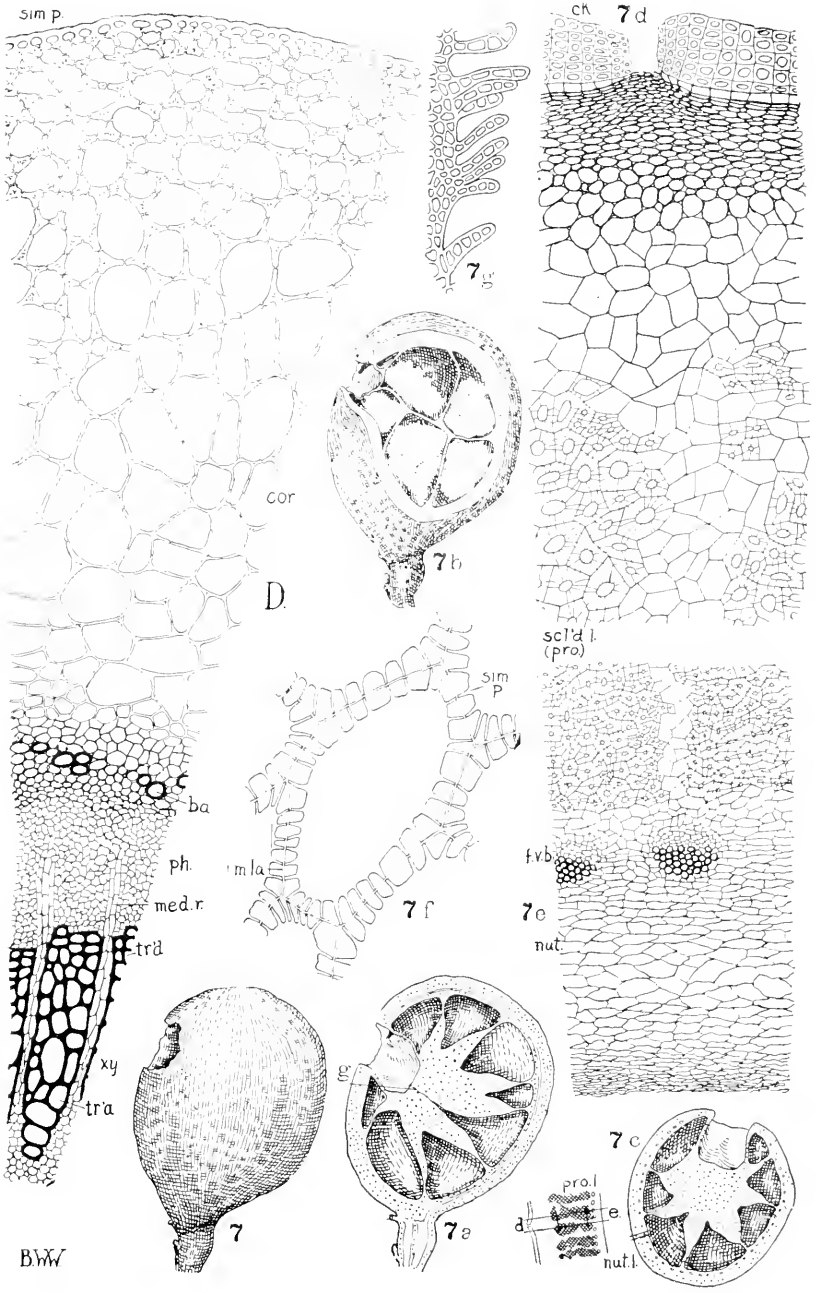

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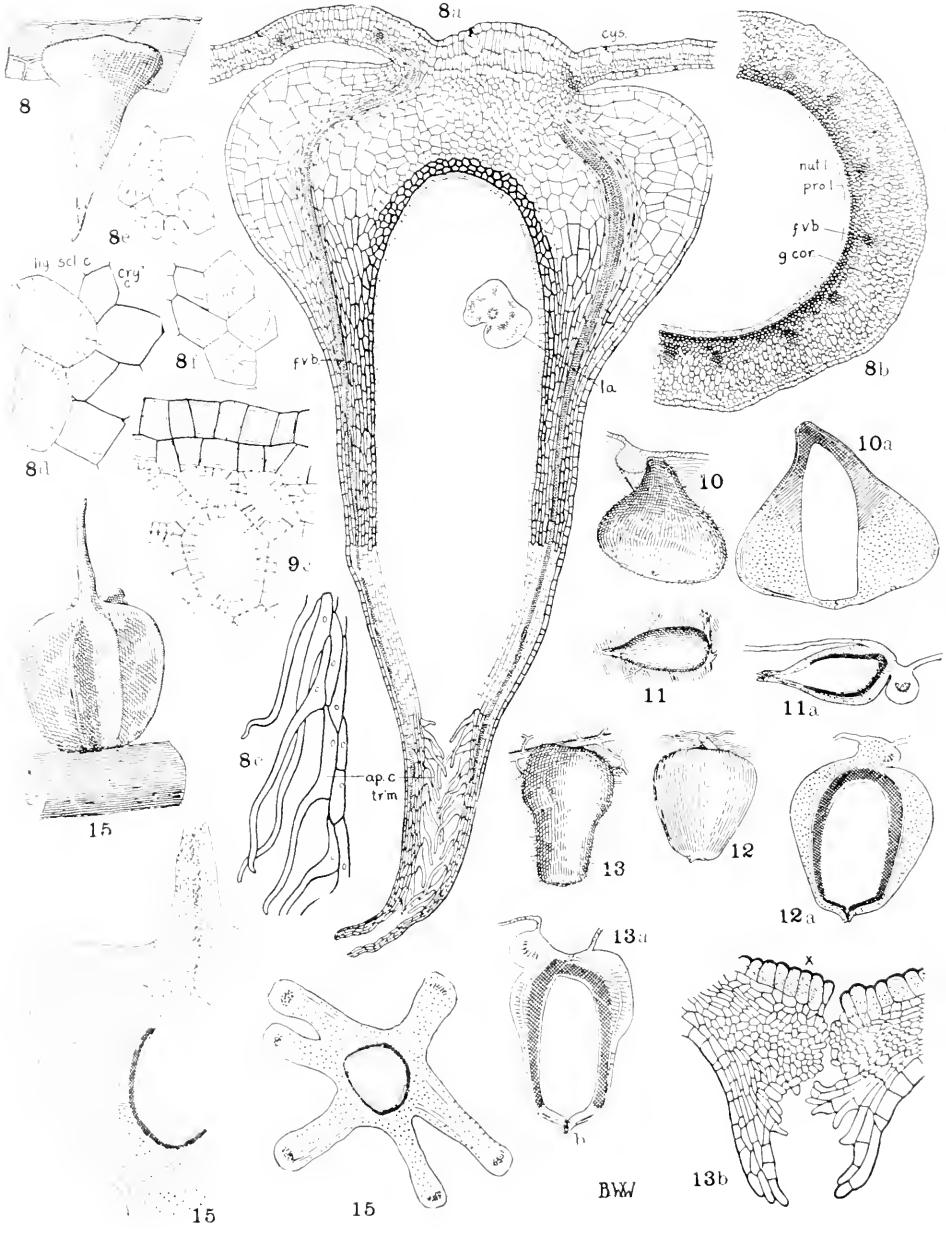

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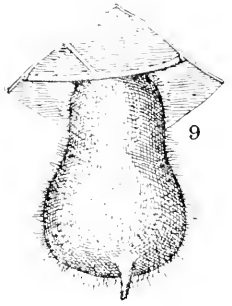

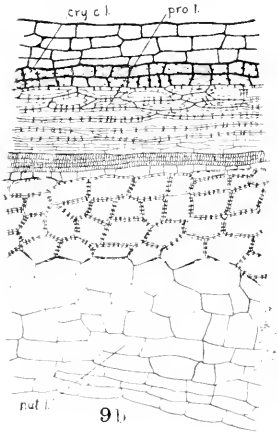

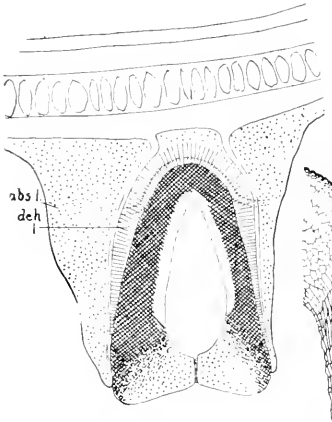

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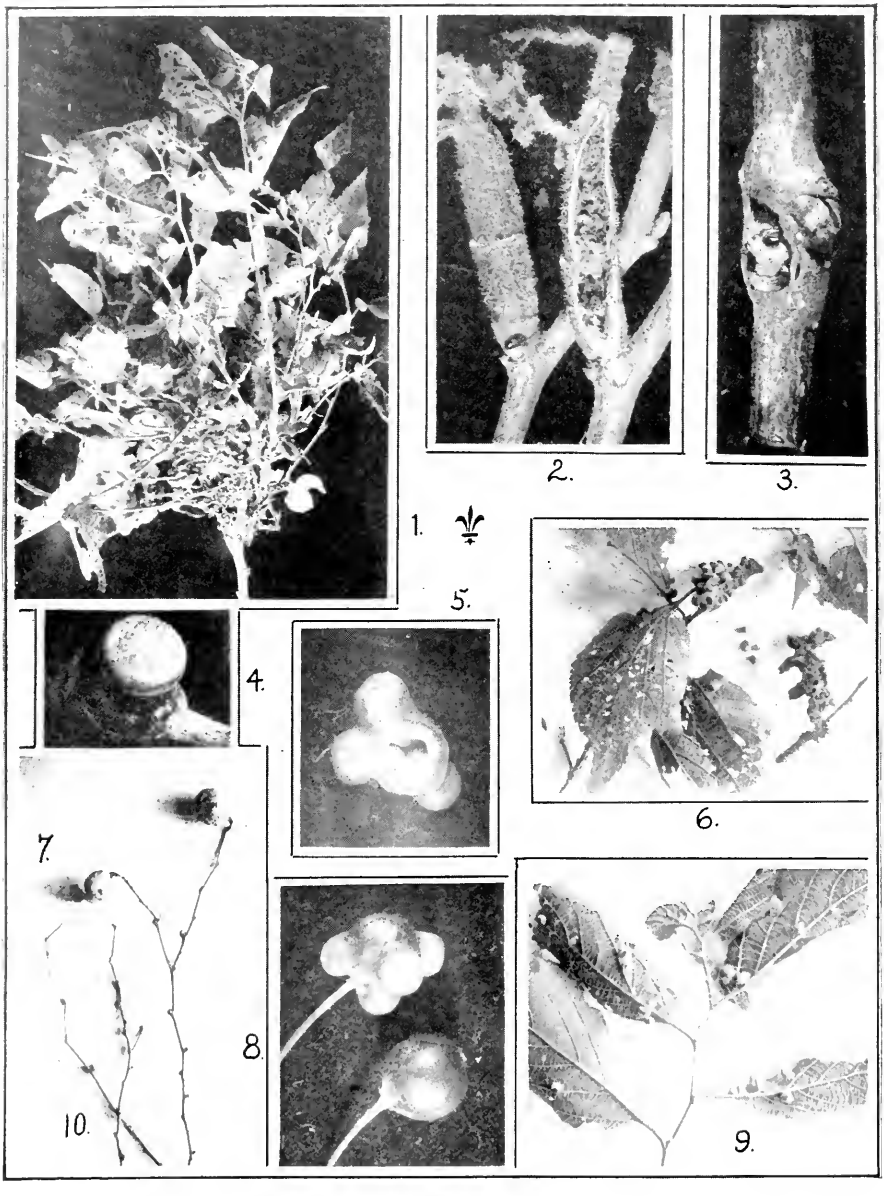

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HOMOPTEROUS STUDIES. PART II.

Morphological Studies of the Superfamily Jassoidea.

ERIC. S. COGAN, M. A.

INTRODUCTION.

The Superfamily Jassoidea comprises a large number of small or comparatively small Homopterous insects, which agree in respect to the character of the hind tibiæ. The latter are prismatic in shape and are armed with a row of spines on their posterior margins. The head varies in shape and may be angular or rounded, produced or shortened. The eyes are located on the lateral margins of the head, and the breadth across them is frequently the widest part of the body. The antennæ are usually inserted on the face between the eyes. The thorax varies considerably, but in all the pronotum is the most pronounced region. There are two pairs of wings, the first pair being developed as tegmina and are usually coriaceous, while the second pair may be membranous. In some forms the elytra are reduced in size.

The superfamily is generally subdivided into four subfamilies, viz.: Bythoscopidæ, Tettigoniellidæ, Jassidæ and Typhlocybidæ, the subdivision of the first three being based on the location of the ocelli, and of the last, on the character of the venation of the elytra. In the Bythoscopidæ, the ocelli are situated on the front below the border of the vertex; in the Tettigoniellidæ they are on the disk of the vertex, while in the Jassidæ they are to be found on the border of the vertex or between the latter and the face. In the three subfamilies mentioned, the elytral nervures fork on the disk, while in the Typhlocybidæ the nervures fork at the base and run to the apex of the elytron without further dividing. Again in the last named family the ocelli may or may not be present. The various subfamilies are further subdivided into a number of genera, and frequently into tribes and divisions.

The chief object of this investigation has been to obtain a definite understanding of the external and internal anatomy for the group generally and to establish homologies with the

other Homopterous families. Very little work has been done on the anatomy of the Jassids, and as far as the writer is aware, no complete treatment of any phase of the morphology has yet been offered. Considerable work has been accomplished on the other Auchenorrhynchous families by Muir, Kershaw, Licent, Pantel, Bugnion, Sulc and others, but the only treatment of the Jassoid anatomy is to be found in the general discussions of systematic works on the group. Thus the works of Signoret, Burmeister, Flor, and Melichar contain general discussions of the external anatomy, which are necessary for taxonomic purposes. The wings and their structure have been ably treated by Metcalf, and only mention will here be made of this phase.

Since the only work on the external anatomy of the Jassoidea has been done by systematists and for taxonomic purposes, Professor Osborn suggested to the writer that an investigation into the morphology of the group would be of some avail, and accordingly the work was undertaken. The scope of the investigation is confined to the four families. A common and seemingly generalized species was selected from each family and in the main the studies here noted were conducted on these. For the Bythoscopidæ, Agallia sanguinolenta was selected chiefly because the material, both adult and nymph, was abundant and readily obtainable; the same may be said of Draeculacephala mollipes for the Tettigoniellidæ, Deltocephalus inimicus for the Jassidæ, and Empoasca mali for the Typhlocybidæ. In many cases species belonging to other genera were studied and compared with the above where such was necessary. To Professor Osborn the writer wishes to express his indebtedness for directing the investigation, and for helpful criticism and suggestion.

Methods.

The material for gross dissection was killed and preserved in a 4 per cent. solution of Formalin and found to be quite satisfactory. Some specimens were killed in hot water and preserved in 70 per cent. alcohol. In many cases material which had recently been collected in the field was killed in 100 per cent. alcohol and dissected and examined immediately. All dissection was accomplished by means of a Bausch and Lomb binocular microscope. For the dissection of the smaller

insects, a shallow dissecting pan made by filling a watch glass with paraffin, proved very convenient. The study of many of the chitinized parts was facilitated by previously boiling the specimens in a 10 per cent. solution of potassium hydroxide, washing in water and examining in glycerine or alcohol. The former proved very suitable, and has the advantage in that it evaporates very slowly. In the dissection of the reproductive organs and the digestive apparatus, normal salt solution was used to float out the organs. Some of the immature forms were conveniently studied by simply killing in Xylol and mounting in balsam almost immediately. Certain structures, such as the tracheal system, show up clearly when treated by this method.

Material for sectioning was killed mainly by two methods. Hot water was used where the insect has recently moulted and the chitin had not yet hardened. Carnoy A (Glacial acetic acid one part, to absolute alcohol three parts) proved to be a very good fixing fluid. Practically all the material for sectioning was killed by this method. Delafields haematoxylin and eosin were the stains used for staining sectioned material. Staining in toto did not prove satisfactory. Picric acid for staining chitin was used to some extent. The material was embedded and cut in paraffin with a melting point of 55 C.

THE HEAD.

External Anatomy. (Pl. XXI, XXII, Figs. 1, 2, 3, 4, 5, 7, 25–31).

The different regions of the Jassoid head have been well defined by systematists in the group and before proceeding to a discussion of the structure, it will be as well to outline these regions, which now, for the most part, are of interest because of their place in the taxonomy of the superfamily. The dorsal region, i. e., the portion of the head between the compound eyes is termed the vertex (v), and in some of the families it bears the paired ocelli (o). Although not a definite sclerite, it serves as a good "landmark" for descriptive purposes. The region from the anterior edge of the vertex to the first apparent transverse "suture" is regarded as the front ("frons"); its lateral margins are limited by the longitudinal sutures which run from the antero-lateral edges almost to the antennæ and frequently to the anterior edge of the head. Attached to the

anterior edge of the frons is the broadly rectangular clypeus, and at the distal edge of the latter is seen the small peglike labrum. At the sides of the frons and clypeus, two small semi-circular plates are seen, these are the loræ. The genæ are the large regions extending from beneath the eyes to the anterior edge of the clypeus and completely surrounding the loræ. The rostrum or beak projects from under the surface of the clypeus and encloses the setæ. The head is greatly deflexed with the result that the rostrum lies between the anterior coxæ and projects in a caudal direction.

The same regions as are seen in the Jassoid head are to be differentiated in the Cicada, or any other of the Auchenorrhynchous Homoptera. In 1896 Marlatt drew attention to the fact that the frons of Cicada septendecim was really the clypeus, that the clypeus and labrum constituted the labrum, and that the loræ were the external representatives of the mandibles, while the genæ were the corresponding pieces of the maxillæ. No attempt was made to homologise the various parts, until the work of Muir and Kershaw appeared in 1911. From a study of the external and internal anatomy as well as the development and embryology of both Homopterous and Heteropterous forms, these authors concluded that the "frons of many writers was the clypeus, and their clypeus was the labrum. The loræ have no connection with the mandibles, but are lateral developments of the clypeal region. The dorsal and outer pair of setæ are the mandibles, developed direct from the first pair of appendages behind the stomodaeum of the embryo, and articulated in their normal position, viz., on the oral margin between the clypeus and the maxillæ. The ventral and inner pair of the setæ are part of the maxillæ developed directly from the distal joint of the second pair of appendages behind the stomodaeum of the embryo, the basal joint being directly developed into the maxillary plate." In a paper on the Development of the Mouthparts in Homoptera, the same authors conclude that "(1) The mandibles and maxilla arise as in other insects, the former being articulated in an approximately normal position. (2) The Homopteran and Heteropteran mouthparts arise and develop in the same manner. (3) There is no mandibular plate. (4) The tentorium agrees essentially with that of other insects. (5) The maxillary seta does not represent the palpus, but may be a development

of the palpifer or the combined lacinia and galea. (6) The maxillary-plate represents the cardo and stipes." In their discussion of the Homology of the Hemipterous mouthparts, no reference is made to the Jassoidea, except that the Tettigoniellids can be easily homologised with the Cicada. Beyond this reference to the Jassoid head the writer has been unable to find further treatment of the subject.

In the following discussion of the Jassoid head, the fixed parts will be considered first and then the free or movable parts.

Fixed Parts of the Head. (Pl. XX, Figs. 1, 2, 3, 4, 5).

The Jassoidea agree with the other Hemipterous families in the general arrangement of the head and mouthparts. The head is greatly deflexed and the mouthparts are attached to the caudo-ventral portion of the capsule, with the result that the beak or so-called proboscis is directed caudally between the first pair of thoracic legs.

Head-Capsule.—As in a generalised insect, the head of the Jassid is composed of a number of sclerites, which have become united to form the head-capsule, and this becomes the external skeleton of the head. To this capsule, the various appendages of the head are attached and articulated. In the head it will be found that no trace of the primitive sclerites forming the head-capsule is to be found, for they have either disappeared or amalgamated with other sclerites. The various regions on the Jassoid head were indicated before, and only those areas which can be definitely recognized as sclerites will be considered here.

The dorsal region (v) of the head (i. e., the vertex) is not separable from the front or frons (Fr), and there is no trace of a suture between them, as one would expect. Together with the genæ and occiput, the vertex and front constitute the epicranium.

The vertex (v) varies considerably in size from a mere narrow region in the Bythoscopidæ to a greatly elongated area in the Tettigoniellids (especially in the Tribe Dorydini). It usually bears the paired ocelli (o); thus in the Family Tettigoniellidæ they are located on the disk or surface, in the Jassidæ on the cephalo-lateral margin near the eyes, and in the Typhlocybidæ (when present) also on the cephalo-lateral margin. But in

the case of the Bythoscopidæ they have been carried over and down on the face, while the dorsal surface of the vertex is greatly reduced.

The Front, although a true sclerite, is not readily differentiated from the following sclerite—the clypeus (clyp.)—the suture between them being obsolete, but its position can be judged by the fact that the anterior arms (i. a.) of the tentorium are invaginated on each side, where the suture should normally end. The front usually, at least in the more generalized insects, can be identified owing to the fact that it bears the median ocellus, but no trace of such an ocellus is to be found in the Jassid head. The frontal region ("frontal ridge") then would be the area between the cephalic margin of the head and a transverse line connecting the invaginations of the anterior arms of the tentorium. In the Jassoid head these invaginations occur at the cephalic end of the maxillary suture, on the so-called mandibular plates or loræ. Its lateral margins would be defined by the longitudinal sutures on either side of the head.

The clypeus (clyp.) is the sclerite attached to the frons along its anterior margin. In the Jassid head as in other Homoptera, it is not easily distinguished from the front; it is a broadly rectangular sclerite, generally somewhat convex with its lateral margins developed into two plates (loræ) which attach along the sides of the labrum. These two plates (the loræ or so-called mandibular plates) have long been regarded as the external pieces of the mandible, although in reality they have no connection with the mandibles. Muir and Kershaw have shown conclusively in their work on the development of the mouthparts of the Homoptera, that the mandibles become enclosed within the head in the course of development. No true suture exists where these two plates are in relation to the labrum, but their basal portion is attached strongly to the middle piece of the clypeus. If we consider the mesal piece as the clypeus proper, then the lateral developments might be regarded as the antecoxal pieces of the mandible.

The labrum (labr.) is the upper lip and is attached to the anterior margin of the clypeus. It constitutes the roof of the mouth and is differentiated with difficulty from the clypeus. However the anterior margin of the clypeus is connected with the pharynx by two small developments of the tentorium, and these

mark the region where labrum and clypeus meet. The shape of the labrum is broadly rectangular, with the anterior margin generally rounded off, and forming a covering for the basal joint of the labium. Projecting from under its anterior margin and fitting into the groove at the base of the labium is the small, peglike epipharynx (epi.). On an external view the epipharynx appears as part of the labrum, but on close examination it will be seen to run back as the dorsal wall of the pharynx.

The Occiput or the posterior part of the dorsal surface of the head can not be differentiated from the vertex. However, by viewing the head in its caudal aspect it may be seen as the large sclerite surrounding the occipital forearm. Attached to the ventral surface of the occiput, is the gula or gular region, which is very small in the Jassoid head, owing to the deflection. The gula consists of a small membrane attached at one end to the base of the occiput and at the other to the basal joint of the labium.

The Genæ proper cannot be distinguished from the maxillary plates—an amalgamation of the two sclerites taking place early in the development of the insect's head. No trace of a suture is to be found and we can only refer to the genæ in general terms as that region surrounding the compound eyes on either side of the face and attached to the maxillary plates, for the greater part.

Ocelli.—The ocelli (o) where present are two in number. As stated before, in the Tettigoniellidæ (Fig. 5), they are located on the mid-dorsal surface of the vertex, while in the Bythoscopidæ they are situated on the face (Fig. 3). The position in the case of the last named family is probably owing to development of the epicranium, which occupies the greater part of the dorsal region of the face. However, in the Jassidæ and Typhlocybidæ (where present), the ocelli are located on the cephalo-lateral margins of the head. On examining the internal structure of the head, it will be found that branches of the dorsal arms of the tentorium proceed to the head just beneath the ocelli. This was found to be the case in practically all the forms examined. The ocelli are small, clear, circular or oval structures, which are generally raised above the general level of the head. Frequently they are colorless or glassy, but in some cases they are pigmented with red or black.

Compound Eyes—The compound eyes (E) occupy the greater part of the dorsal aspect of the head at the sides of the vertex. They are large oval or semicircular bodies, which extend back to the anterior margin of the pronotum. In the immature forms they are relatively larger than in the adult and are more rounded. The character of the facets is the same as that of a generalised insect, although the number of these facets is exceedingly great.

Movable Parts of the Head. (Pl. XX, XXI, Figs. 6,7,13,16,17).

Antennæ (Figs 18–21).—The antennæ (A) are for the most part setaceous in form; structurally there is very little difference between the morphology of the antennæ in the various forms, although it will seem as well to indicate here the more important of these. The number of segments or joints varies considerably and frequently cannot be distinguished at the distal ends. The basal segment and those adjoining it are the most modified in size. In the males of Idiocerus (Bythoscopidæ) the distal joints of the antennæ are developed into small oval plates, which Hansen has regarded as sensory structures. In many of the Tettigoniellids and Jassids, small hairs or spines are developed on the basal joints of the antennæ. The antenna of Deltocephalus inimicus figured shows this structure (Fig. 19). These spines may have some sensory function, although no trace of sense cones were found on them. The antennæ are inserted on the face between the compound eyes and the longitudinal suture of the front. In some cases the point of insertion may be a deep cavity, in others it may be shallow. In some of the Bythoscopidæ the cavity is overlapped by a distinct ledge.

Labium—(Pl. XX, Figs. 9, 13). The beak or proboscis of the Jassid mouthpart is the labium or lower lip. It is relatively short and thick, circular in outline, and is three-jointed. The distal joint, or tip of the labium is the largest, the proximal the smallest and the middle is about intermediate in size between the two. Externally the labium appears to emerge from under the labrum, but a closer examination will reveal the fact that the tip of the epipharynx, a small, peg-like structure, which is attached to the anterior end of the labrum, fits into a narrow groove on the surface of the labium and gives it some means of support in one direction. Ventrally the labium

is attached by its strong lateral and central muscles to the gula and to the body of the tentorium. The membrane of the proximal joint is developed into a central chitinous rod, to which attach the central muscles (c); at the sides the muscles attach directly to the basal joint at one end and to the gula at the other. The labium forms the floor of the mouth, and encloses the mandibular and maxillary setæ. As the mouth-parts of the Jassid are fitted for sucking, the two pairs of setæ are in close relation in the trough which runs the full length of the labium. This trough is shallow, and closed for the greater part beyond the epipharynx. The maxillary setæ form the sucking tube through which the plant juices are drawn. It is quite possible that the mandibles form the piercing organs, by means of which the maxillæ are enabled to function. Two sets of muscles are to be found in the labium—circular (c. m.) and longitudinal. The longitudinal muscles enable a back and forward movement, such as protrusion and withdrawal, while the circular muscles allow of an up and down movement. The attachment of the labium to the gula is not very strong and frequently on removing the head from the body, the labium will remain attached to the anterior edge of the prosternum. The setæ are capable of withdrawal from the trough of the labium, and may be free—this is often the case in nymphal forms. At the anterior edge of the labrum where the setæ emerge from the head capsule into the labium, a small membrane covers the entrance to the labium, making the structure airtight. This is necessary when it is considered that the plant juices constituting the food of the insect must be sucked up into the pharynx.

The tip of the labium is rounded and the setæ are protruded through a small hole at the end. The external region of the labium is chitinized, and is set with numerous hairs or spines. In feeding, the labium is applied to the plant leaf or tissue and forms a guide for the setæ. It however, does not enter the plant tissue. It is quite possible that the close application of the labium to the plant will render the connection airtight so that the juices may more readily be sucked up.

Maxillæ—(Pl. XX, Figs. 7, 17, 5, 4, 3). If the head of a Jassid be examined, two large plates (mx. pl.) forming the sides of the face and the lateral covering of the mouth, will be

found. These are the maxillary plates (mx. pl.), and they occur in all Homoptera. Although the maxilla are fused with the genæ, they can be distinguished from the latter in that they articulate with the maxillary setæ (mx. s.), which are enclosed within the head-capsule. The maxillary plates extend around the sides of the face and constitute the border; they completely surround the clypeus and meet anteriorly beneath the labrum, where they are connected by a membrane. At the sides the plates are turned down and under, forming the part of the ventral surface of the head. Distally they turn back on the under side of the head, and develop into two rectangular chitinous plates—with which the maxillary setæ articulate. The maxillary setæ are attached to these chitinous plates, which in turn are hinged to the body of the tentorium (t. b.).

The maxillary setæ (mx. s.) resemble the setæ of other Homoptera; they are long and slender for the most part, but their proximal basal region is swollen, and attaches to a small tendon (t.), which passes dorsally into the retractor muscles (mx. r.) of the setæ. A membrane sleeve surrounds the seta, as far as the entrance to the labium. The strong protractor muscles (mx. p.) of the maxillary setæ are attached to the maxillary plate, while the retractor muscles attach to the head-capsule at the sides of the occiput. The articulation of the seta is on the inner side of the maxillary plate and it can easily be seen by reference to the figure (Pl. I, Fig. 7) how the maxillæ can be worked forward and backward.

The exact homology of the maxilla in Homoptera is a question on which no little discussion has arisen. The amalgamation of the maxillary plate with the genæ, would lead one to believe at once that the whole of the plate at that side of the clypeus constitutes the gena, but on examining the internal structure, and the connection of the maxillary plate with the maxillary seta, it can readily be seen that the maxillary seta is intimately connected with the maxillary plate. Added to this the invaginations of the posterior arms of the tentorium are to be found at the sides of the occipital foramen, and are adjacent to the attachment of the maxillary plates with their setæ. In all the insects so far examined, the invaginations of the posterior arms of the tentorium have always been associated with the point of attachment of the maxilla.

Mandibles—(Pl. XX, Figs. 6, 16, 2, 4, 3). Viewing the head on the inside from its caudal aspect, the two pairs of setæ, viz., the mandibular (m. s.) and maxillary setæ, can be seen attached to the head capsule. These two pair of setæ are in rather close relationship, but with careful dissection it will be seen that the more dorsal pair are articulated with head-capsule, between the maxillary plate and the clypeus. The posterior end of the mandible is produced into a small tendon (t) to which attach the strong retractor muscles (m. r.) which attach in turn to the head-capsule at the sides of the occipital foramen. A small tendonous rod (m. a.) connects the mandibular seta with the latero-posterior edge of the clypeus. While the mandibular seta is intimately related to the maxillary seta in the labium, the two are separate within the head-capsule. The mandibles are capable of being withdrawn and protruded within limits owing to the muscles, which are connected with the posterior end. The retractor muscles (m. r.) attach to the head capsule on the inner side of the clypeus. The position of the invagination of the anterior arms of the tentorium, which are associated with the mandibles, enables one to homologise the mandibular setæ in the Jassoidea with the mandibles in the Cicadidæ and other Homoptera.

The identity of the mandibular plate or lora, has been well demonstrated by the work of Muir and Kershaw on the development of the Homopterous head, wherein it is shown that the mandibles become completely enclosed within the head-capsule. Although this question has been much discussed, from various points of view, it seems to the writer clear that the evidence favors the interpretation of the mandibular setæ as representing the entire mandible. The articulation of the mandibular setæ viz., between the clypeus and the maxilla is the normal position, and further the invagination of the anterior arms of the tentorium add additional weight to the interpretation.

The structure and morphology of the mandibular seta resembles very much that of the general Homopteron; the tips are barbed, with the barbs (b. a.) pointing backward. As stated before, their function is probably that of piercing the plant, to enable the maxillæ to perform the sucking function. Like the maxillary, the mandibular setæ are surrounded for their proximal half with a membranous sleeve.

Internal Anatomy. (Pl. XX, Figs. 2, 3, 4, 5, 8, 9, 10, 11; Pl. XXI, Fig. 22).

In the following discussion of the internal anatomy of the head, those structures previously mentioned will be omitted and only the parts which pertain directly to the internal structure will be considered.

Tentorium—(Figs. 4, 5). In the heads of all insects there is to be found a definite arrangement of supporting, chitinous structures, which owe their origin to three pairs of primary invaginations of the body wall. The structure itself consists of a system of rod or plate-like bodies, which constitute the tentorium or internal head skeleton. In the Jassid head this skeleton is present, but in some respects it has been modified. The three pairs of arms which compose the tentorium are known respectively as the anterior, dorsal and posterior arms. The anterior arms (i. a.) are invaginated on the cephalo-lateral edges of the clypeus; in the Jassid head this invagination is to be found at the upper corner of the so-called mandibular plate; it persists as an opening and can be distinctly seen in a specimen which has been boiled in KOH. In many insects the points of the invaginations do not persist in the adult. The anterior arms (i. a.) are always associated with the mandibles, and in the Jassid head they are to be found near the articulation of the mandibular setæ. The dorsal arms (d. a.) are invaginated beneath the antennæ and are easily seen in the head of Deltocephalus inimicus or any Jassoid. They are always associated with the antennæ, and in this case they occupy their normal position. While the invaginations themselves are not readily seen, the arms are quite prominent. The posterior arms (i. p.) are invaginated at the sides of the occipital foramen and are near the attachment of the maxilla. The upper ends of the posterior arms are connected by a chitinous bridge (the maxillary bridge of Muir and Kershaw), which is the body of the tentorium (t. b.). The latter divides the occipital foramen into two parts.

In the Jassoid head the parts of the tentorium have been modified to a certain extent, but nevertheless they can readily be homologised with the corresponding structures in the Cicada and other Homoptera. From the invagination of the anterior arms, on either side of the head, two small chitinous structures

run forward to the anterior edge of the clypeus; here they attach to the dorsal region of the clypeus, and at the same time are connected with one another by a narrow bridge, which is scarcely visible. From the anterior region of the pharynx two small tentorial structures attach to the anterior arms and form the chief means of support of the pharynx.

The posterior arms, the invaginations of which are connected by the body of the tentorium (t. b.), run forward along the ventral region of the head, as far as the salivary pumping apparatus (s. p.), where they attach on either side to the syringe. The body of the tentorium is very prominent and on either side it forms a means of support for the maxilla, to which it is attached. Its median portion supports various muscles, including those of the salivary pump and the labium. Passing up from the invagination, the posterior arms nearly surround the occipital foramen and join with the corresponding dorsal arms. The connection is not so very prominent, and in all the forms examined, the junction was confined to a mere tendon. The dorsal arms, which are to be found beneath the antennæ, are quite prominent in the dorsal region of the head. The size of the dorsal arms varies somewhat in different species; in Draculecephala mollipes they are short and branched, while in Deltocephalus inimicus and Agallia sanguinolenta they are much longer. Between the invaginations of the dorsal and anterior arms, small tendonous plates are to be seen.

In the Jassoid head, the correlation between the tentorial structures and the appendages of the head is to be found and forms the basis for their interpretation.

Epipharynx—(Pl. XX, Figs. 14, 1, 2, 3, 15). The anterior end of the dorsal plate of the pharynx is differentiated into the epipharynx (ep.), which is seen externally as the small peg covering the base of the labium. This structure is closely related to the labrum and in fact, the separation of the two is a difficult matter. The pharynx (ph.) continues along the under side of the labrum and passes out as the epipharynx. The epipharynx is fused with the anterior edge of the labrum, but a trace of the former condition can be seen.

Hypopharynx—(Pl. XX, Figs. 8, 15). The anterior end of the ventral plate of the pharynx is the hypopharynx (hyp.) and is a prominent structure in the mouth-cone of the Jassid.

It is broadly spoon-shaped, with the anterior end slightly pointed. Beneath it, the salivary pumping apparatus (s. p.) occurs and is in close relationship with its lower surface. The hypopharynx is heavily chitinized. The opening of the pharynx into the suction canal of the labium is surrounded by hypodermis, which encloses the setæ.

Pharynx—(Pl. XX, Fig. 5). The chitinous pharynx, as in all Hemiptera, constitutes a pumping apparatus, by means of which plant juices and other food are withdrawn into the digestive canal. The pharynx is a comparatively short, simple, chitinous tube, supported by strong muscles. The dorsal plate is somewhat elastic, and is capable of being withdrawn from the ventral plate by the pharyngeal muscles (ph. m.), which attach to the head-capsule along the inner surface of the clypeus. Apparently the pharynx is about the most powerful organ of the head, as the preponderance of pharyngeal muscles is obvious. The pharynx passes back over the body of the tentorium into the membranous esophagus.

The Salivary Pumping Apparatus—(Pl. XX, Figs. 8, 15). This characteristic Hemipterous structure is to be found beneath the base of the hypopharynx. It consists essentially of a broad spoon-shaped structure, into which fits the plunger (p.); the latter is slightly smaller than the spoon or barrel (b. a.) and functions as the driver of the apparatus. The plunger is developed backward into a thick rod (r.), to which attaches at its end the protractor muscles (p. p. s.). The united salivary ducts (s. d.) open into the base of the barrel, and by the forward motion of the plunger the saliva is forced forward through a small canal (s. d. h.), which leads to the anterior edge of the hypopharynx. At their entrance to the barrel the salivary ducts are chitinized. The protractor muscles (p. p. s.) of the plunger rod attach to the body of the tentorium, while the retractor muscles (p. r. s.) attach on the under side of the rod at one end and to the maxillary plates at the other. The plunger is thus capable of a forward and backward motion, by which means the saliva is pumped into the canal.

Salivary Glands—(Pl. XXI, Fig. 22). In the Jassoid head four separate salivary ducts are to be found; two pairs unite behind the salivary pump into one common duct, but farther back they separate into two pairs, which continue along the

floor of the mouth into the thorax. Both pairs of ducts end in glands, which are long structures, normally located in the abdomen. Each gland is whitish, and rather narrow. The salivary glands secrets the saliva which is carried forward into the pump and thence into the sucking tube.

THE THORAX.

The structure of the thorax was not studied in any degree of detail, and only reference to the more striking features will here be made. As in a generalised insect the thorax is composed of three segments, in order, the pro-, meso- and meta-thorax. The prothorax has undergone considerable modification and the traces of the sclerites seem to have been entirely lost. The dorsum or tergum is the large piece on the dorsal surface; it overlaps the mesonotum. Laterally the prothorax shows little differentiation into episternum and epimeron. The sternal region is reduced to a small piece, which bears the small chitinous apophyses. At the sides the first pair of legs are borne. The mesothorax is large and well developed, comprising a number of sclerites, which are separated with difficulty. Laterally it bears the tegmina and beneath the second pair of legs. The episternum and epimeron are easily recognised in this segment. A noticeable feature of the mesothorax is the great development of the musculature; the large wing muscles are very prominent. The apophyses are strongly developed. The metathorax is striking because of the great development in size of the hind coxæ; the latter are supported by very strong muscles. The sternal surface of the metathorax is almost completely overshadowed by the large coxæ.

THE ABDOMEN.

The Jassid abdomen is composed of at least eight segments, of which the first seven bear spiracles. Each abdominal segment is composed of a dorsal tergite and a ventral sternite, the two being connected by pleural membranes.

The modification of the posterior end of the abdomen for reproductive purposes has brought about a reduction in the number of apparent segments and many of these are recognised with difficulty. In the female the last abdominal segment is known as the pygofer (pyg.); through its dorsal region the anal

tube (an. t.) opens to the exterior. The ventral portion almost completely encloses the ovipositor (ovp.) which is generally a long, rather slender, heavily chitinized organ, hinged to the caudal end of the preceding segment. In its simplest form the ovipositor consists of two strong ventral valves (v. v.), which on being spread apart, expose the two inner valves (i. v.). The latter constitute the main part of the ovipositor and are small, sharp, slender pieces, which fit close together and so form a channel through which the ova may be extruded. The tip of the inner valves are barbed or sickle-shaped. The vagina opens into the anterior end of the channel. Beneath the inner valves are two large pieces which fit close together and compose the dorsal valves of the ovipositor. (d. v.).

The posterior region of the female abdomen as well as that of the male, shows a great deal of variation in the modification and advantage is taken of this for taxonomic purposes. The ventral abdominal segment just anterior to the ovipositor frequently shows a great deal of variation in shape. In the majority of the forms examined, however, the essential details of the female genital armature do not differ strikingly from the above.

In the male the last dorsal segment is known as the pygofer, and as in the female, the anal tube opens on it. Ventrally, the posterior of the abdomen is modified into a series of plates which afford protection for the penis. The uppermost of these plates is connected with the preceding abdominal segment and constitutes the valve (g. v.); it is generally triangular in shape, and extends about half way over the plates beneath. The latter are the genital plates (g. pl.) and are two long, somewhat rectangular pieces, which cover over the penis and penis guides. The genital plates vary considerably in size and shape, and advantage is taken of this character in the differentiation of species. In copulation the ventral valve bends down so as to allow the genital plates to spread apart, and the penis, with its accompanying guides is brought into action. The penis (pen.) is an elongate slender structure, which is strongly chitinized. It is hinged at the base of the pygofer, and is capable of considerable motion in a ventral direction.

Internal Anatomy.

The Digestive System. (Pl. XXI, Fig. 22; Pl. XXII, Fig. 34).

The chitinous pharynx passes back into the membranous esophagus (e. s.), which is a relatively short simple tube. In the metathorax, where the esophagus enters the midintestine, a constriction is noticed and a large food reservoir is developed. The latter structure is comparable to the food-reservoir of certain Fulgoridæ and Cercopidæ. The food-reservoir is a bilobed or double U-shaped structure, which opens into the intestinal coils; its function is probably that of a storage reservoir. From the reservoir the alimentary canal continues as a long, convoluted tube (m. i.) of small diameter; the length of midintestine is about two and a half times that of the body. It ends in the short rectum without differentiating into either colon or ileum. The rectum continues to the anus, which is located on the dorsal surface of the last abdominal segment.

Opening into the midintestine (m. i.) are the long Malpighian tubules (mp. t.); these are difficult to detect in the Jassid, but at length may be seen among the coils of the intestine. They are about the same length as the body and are of small diameter. There are only two pairs so far as was observed.

The food reservoir (f. res.), or crop, in Deltocephalus inimicus occurs entirely within the abdomen and does not enter the thorax. This seems to be the general condition, although in some forms it is to be found penetrating the thoracic region In some forms it occupies a great part of the anterior region of the abdominal cavity.

The digestive system may be readily dissected out of preserved specimens, although some little difficulty is experienced in keeping the coils of the intestine intact. It was noticed that in specimens which had been cleared in carbol-turpentine, there was a tendency on the part of the food reservoir to swell up and telescope through the dorsal wall of the abdomen.

The opening of the alimentary canal to the exterior, i. e., at the anus, is on the last abdominal segment and in the majority of individuals examined it was noticed that the anal orifice was beset with hairs and strong spines. The anal tube is a small structure, which is heavily chitinized. It conveys the feces to the exterior. In most individuals the anal tube is two-jointed, the basal joint being the longest.

Tracheal System. (Pl. XXII, Fig. 33).

The Tracheal System consists of the main trunk (m. t.) system connected with the spiracles (spi.). There are in most forms nine pairs of spiracles; two thoracic, and seven abdominal (I-VII), although in some species the abdominal number may be only six. The thoracic spiracles (t. spi.) are at first rather difficult to detect, but may be found below the wings on the episterna as two small, unprotected holes. On the abdomen the spiracles (ab. spi.) appear as small, elongate, narrow holes, located on the anterior halves of the segments, near the pleural membranes. Each spiracle connects with the main trunk system by a short tube.

The main trunk system (m. t.) comprises the two lateral tubes, which run down the sides of the body and anastomose. The two longitudinal trunks are connected by transverse trachea in the meso- and meta-thorax. The anastomosis in the thoracic trachea is best shown by reference to the Figure (Pl. XXII, Fig. 33). Two large transverse tubes connect the longitudinal trunks in the mesothorax, while in the metathorax the two transverse tubes do not open directly into the main trunks, but connect with the spiracle tube. A small tracheal tube runs between the two thoracic spiracles and gives off the branches which run to the wings. In the nymphs these tubes are very evident, although in the adult they are not so prominent. At the caudal end of the body the two trunks are in close relationship by means of their smaller branches, but no distinct tracheal connection is seen.

From the main longitudinal trunks arise the three systems of branches, the dorsal, visceral and ventral, which ramify through each segment, and portion of the body. Two strong branches are seen in the head, and supply the antennæ, mouth-parts and the viscera of the head with trachea. Branches of the dorsal system can frequently be found in the dorsal muscles of the thorax, and in the peripheral region of the dorsum. The visceral system of branches supports the digestive apparatus and the reproductive organs, while the ventral system is closely connected with the nervous system and the ventral musculature.

Reproductive System. (Pl. XXII, Figs. 35, 36).

Female Organs—The paired ovaries (ov.), are normally located in the third segment of the abdomen, but frequently they occupy the greater portion of the abdominal cavity. Each ovary consists of six ovarian tubes (o. t.) or tubules, although this number is subject to some variation. Holmgren, who has studied the female organs in some detail gives the number of ovarian tubules in a Thamnotettix as twelve or two pairs of six each. Each ovarian tube (o. t.) is attached at a common point to the suspensor (sus), which in turn is supported by a tracheal branch in the dorsal region of the body. The length of the ovarian tubule varies greatly, but it frequently exceeds the abdomen; in many cases, as just before oviposition, the abdomen will be greatly distended by the numbers of eggs in the ovaries and on first examination it would seem that the whole abdominal cavity was filled with ova. In some cases the ovarian tubes may be pressed into the thoracic region, previous to oviposition. All the ovarian tubes unite caudally in a common oviduct (Ovd.) which is short and broad, although in some forms e. g. Cicadula, it may be long. The oviduct is frequently constricted before the opening of the receptaculum seminorum (rec. sem.) which is a semi-circular structure, lying to the side of the oviduct. The size of the receptaculum seminorum varies and may be large or small. Beyond the receptaculum seminorum the oviduct receives two pairs of accessory glands (ag^1, ag^2), which are very long and extend back into the abdomen. The vagina which is the terminal portion of the oviduct, opens into the ovipositor, through which the ova are extruded.

Male Organs—(Pl. XXII, Fig. 35). In the male each testis is composed of a varying number (usually six) follicles (f.). The testes which are located at the posterior end of the abdomen are yellowish in color, and are frequently enclosed in a whitish membrane. Each follicle is about three times as long as broad, and opens into the vas deferens (v. d.) by a separate duct. The vasa deferentia are about four times as long as broad and unite to form the ejaculatory duct (e. d.), which is merely a dilation before the penis or copulatory organ. Small accessory glands (a. g.) enter the vasa deferentia just before the ejaculatory duct.

Musculature System.

The most noteworthy features of the musculature system are the powerful muscles of the posterior region of the abdomen. The pygofer bears the muscles which support and work the strong ovipositor. The longitudinal muscles of the abdomen comprise the small ventral muscles of the body wall and the dorsal muscles. They are segmentally arranged. The lateral muscles of the abdomen are poorly developed and are confined to small strands which are situated along the sides of the body.

Nervous System.

The central nervous system (Pl. XXII, Fig. 32) consists of the brain (supraesophageal ganglion), the subesophageal ganglion, and the thoracic ganglion, with their attendant nerves and commissures.

The Brain (Br.) is relatively large and occupies the greater part of the dorsal region of the head. It emits two pairs of large nerves, which innervate the eyes (On.) and antennæ (An.) respectively. The brain is connected with the subesophageal ganglion by the circumesophageal commissures, which are rather small and not easily recognised. From the subesophageal ganglion small nerves pass to the maxillæ and labium.

The Thoracic Ganglia (T. G.) are fused into one large ganglion, located on the floor of the mesothorax. Small commissures connect the thoracic ganglion with the subesophageal, although the two appear to be continuous. Numerous nerves originate from the thoracic ganglion and pass to the legs, the dorsal muscles and the digestive apparatus.

There are no abdominal ganglia, but two strong nerves are seen passing back from the thoracic ganglion to the caudal end of the body. These two main abdominal nerves (Abd. N.) arise close to one another and are probably the result of the separation of the abdominal ganglia and commissures. They become widely separated as they pass down the body on either side of the median line. Each abdominal segment is supplied with nerves from these two main commissures and in addition the reproductive organs, the digestive apparatus and the excretory system are innervated.

While the Jassid nervous system does not differ very much from that of a generalized insect, it shows a specialization in the absence of the abdominal ganglia. However, this is not

an unusual state for the Homoptera, as Kershaw has shown that in the Fulgorid Pyrops candelaria, the structure and morphology of the nervous system is essentially the same. The abdominal ganglia have probably migrated forward and fused with the thoracic ganglia, leaving the abdominal commissures in their former position.

Circulatory System.

The Circulatory System so far as observed, consists of a long tube, or dorsal vessel, which runs the full length of the body, from the brain to the last abdominal segment. In general it is an undifferentiated tube, in which the blood circulates. The pulsation of the dorsal vessel may be observed by placing a living specimen under the binocular microscope, and watching the rhythmic movements of the abdomen. The vessel reaches the brain, which it supplies with blood and then apparently divides into two branches which pass into the body cavity.

Conclusions.

The studies enumerated above have led me to the conclusion that the Jassoidea can be homologised with the other Homopterous families. The head differs very little from the fundamental and generalised plan of the Cicada, and while the Jassid does not show the development of the prominent sulci, the structure of the mouthparts and head is very similar. The mandibular setæ represent the mandibles and the maxillary setæ, together with the maxillary plate constitute the maxillæ. While for systematic purposes we have been applying general terms to the regions of the head, it would seem impossible to change the nomenclature, so as to correspond with the morphological details. The labrum and clypeus are scarcely distinguishable from one another and the epipharynx is closely related to the labrum. The tentorium is present and the invaginations occur as in all insects. There is a well-developed salivary pumping apparatus. The epicranium is subject to some modification in size. There is a well developed nervous system, which is almost entirely cephalo-thoracic. The digestive system, in the development of a food-reservoir agrees with the other Auchenorrhynchous Homoptera. In general the plan and morphology of the internal organs follows that of a generalised Hemipteron, and the various modifications which occur in structure are just as likely to be specific as well as generic.

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ABBREVIATIONS.

A.—Antenna.
Ab. Spi.—Abdominal Spiracle.
Ag.—Accessory gland.
An.—Anus.
An. t.—Anal tube.
A. N.—Antennal Nerve.
a. m. s.—Articulation of the mandibular seta.
Abd. n.—Abdominal nerve.
Br.—Brain.
BA.—Barrel of salivary pump.
ba.—Barbs of mandibular seta.
C. C.—Circumesophageal commissure.
C.—Central muscles of labium.
c. m.—Circular muscles of labium.
Clyp.—Clypeus.
D. V.—Dorsal valve of ovipositor.
E.—Eye.
E. d.—Ejaculatory duct.
Es.—Esophagus.
E. p.—Entrance to penis.
ep.—Epipharnyx.
G. Pl.—Genital plate of male.
G. V.—Genital valve of male.
F.—Follicle.
Fr.—Front.
F. Res.—Food Reservoir.
Hyph.—Hypopharynx.
i. a.—Invagination of the anterior arms of tentorium.
i. d.—Invagination of dorsal arms of tentorium.
i. p.—Invagination of the posterior arms of the tentorium.
i. v.—Inner valve of ovipositor.
L.—Lateral muscles of labium.
lab.—Labium.
labr.—Labrum.
lab. ms.—Labial muscles.
m. a.—Attachment of mandibles to head-capsule.
mx. a.—Attachment of maxilla to head-capsule.
md.—Mandible.
mx.—Maxilla.
mi.—Midintestine.
m. p.—Protractor muscles of mandibular seta.
mx. p.—Protractor muscles of maxillary seta.
m. t.—Mandibular tendon.
mx. t.—Maxillary tendon.
Mx. pl.—Maxillary plate.
M. T.—Main Trunk of tracheal system.
Mp. T.—Malpighian Tubules.
m. r.—Retractor muscles of mandibular seta.
mx. r.—Retractor muscles of maxillary seta.
O.—Ocellus.
O. N.—Ocular nerve.
O. T.—Ovarian tubes.
Ov.—Ovary.
Ovd.—Oviduct.
Ovp.—Ovipositor.
O. F.—Occipital foramen.
Pen.—Penis.
P.—Plunger of salivary pump.
Ph.—Pharynx.
Ph. m.—Pharyngeal muscles.
Pl. c.—Plates of Clypeus.
Pyg.—Pygofer.
pps.—Protractor muscles of salivary pump.
prs.—Retractor muscles of salivary pump.
R.—Rod of plunger.
Rec Sem.—Receptaculum Seminorum.
Rec—Rectum.
S.—Seta.
sg.—Salivary gland.
sd.—Salivary duct.
Subg.—Subesophageal ganglion.
s. p.—Salivary pump.
sd. h.—Salivary duct to Hypopharynx.
Sus.—Suspensor.
T.—Tendon.
T. Spi.—Thoracic spiracle.
Tes.—Testis.
Tg.—Thoracic ganglion.
ta.—Arms of tentorium.
tb.—Body of tentorium.
ts.—Tentorial support.
tr.—Trachea.
V.—Vertex.
VV.—Ventral valve of ovipositor.
Vag.—Vagina.
V. D.—Vas Deferens.

EXPLANATION OF PLATES.

Plate XX.

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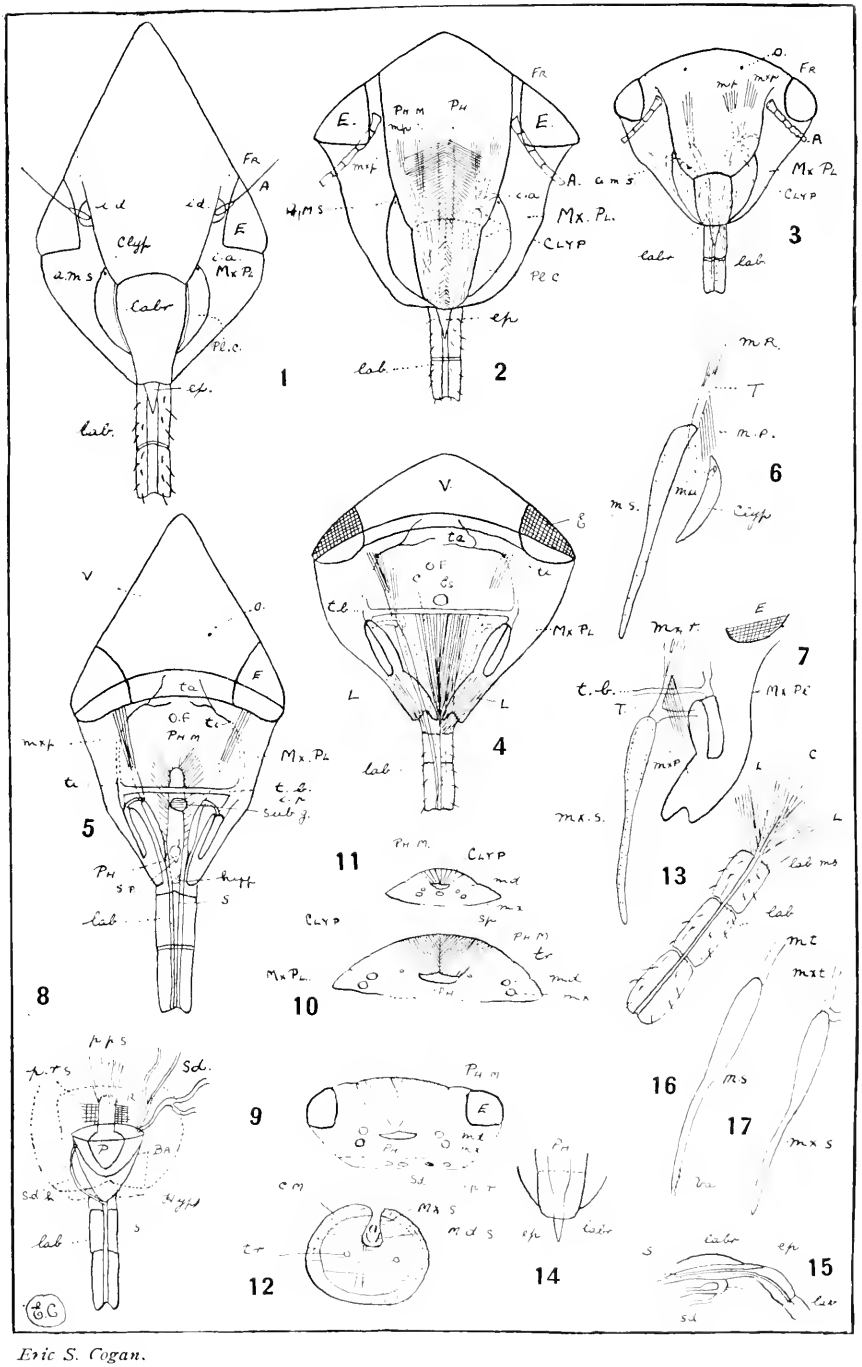
Fig. 34. View of digestive system of Athysanus exitiosus.
Fig. 35. General dissection of the male reproductive organs.
Fig. 36. General dissection of the female reproductive organs.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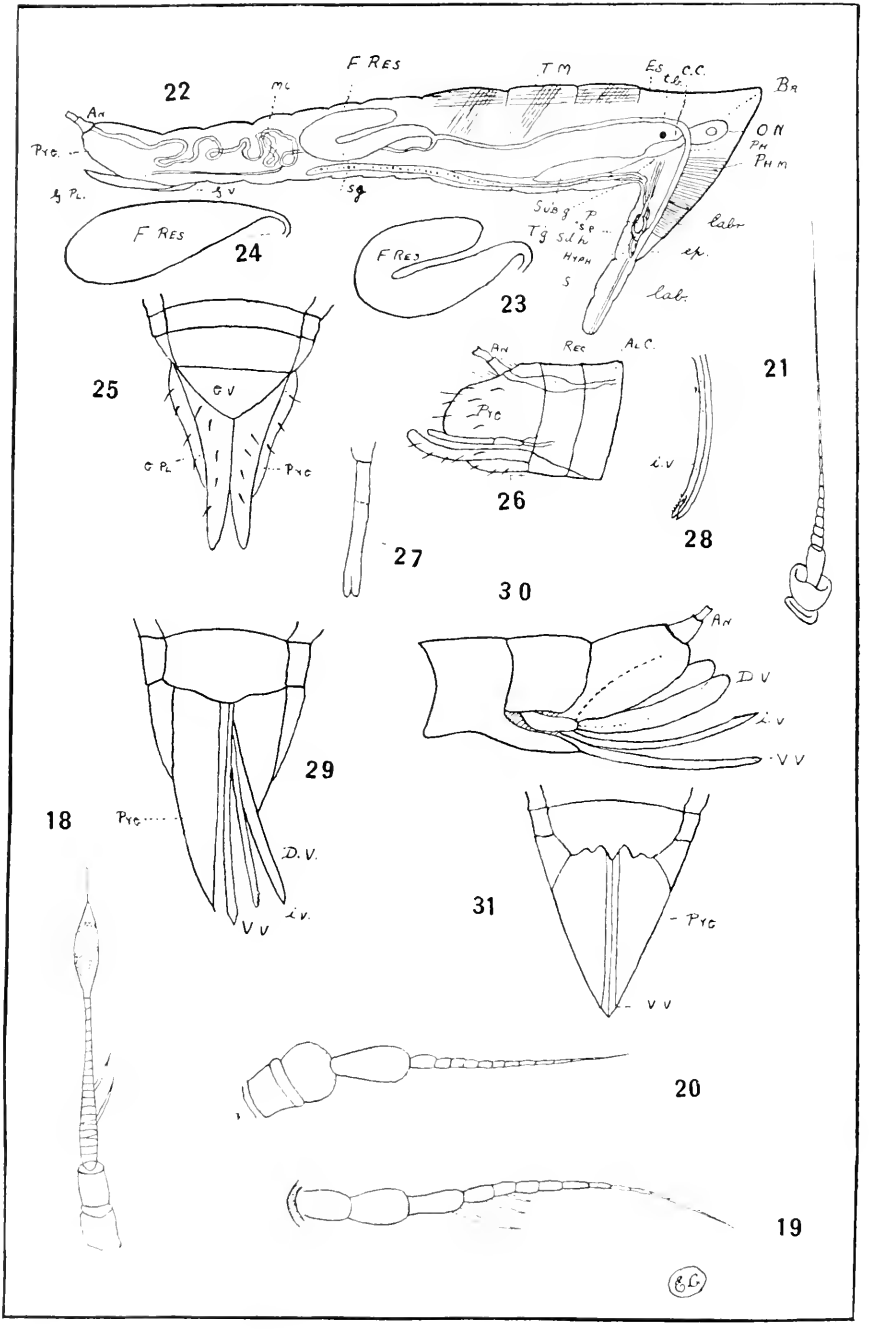
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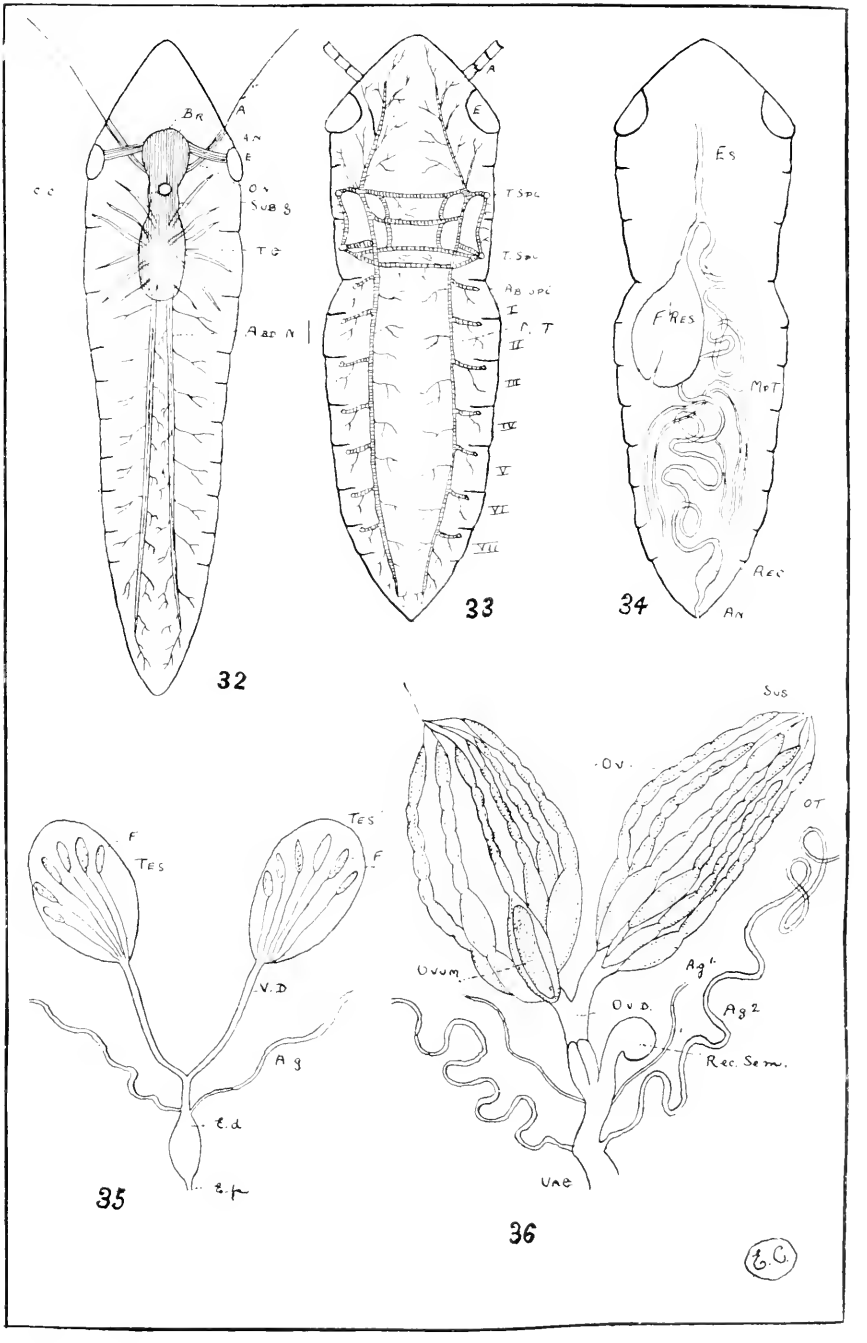
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Eric S. Cogan.

A NEW TINGID FROM TENNESSEE.

CARL J. DRAKE.

The genus *Leptostyla*, founded by Stal in the *Enumeratio Hemipterorum*, Band. III, p. 111 et 125 in 1873, was based on three new species of Tingitidæ from Rio Janeiro, Brazil. Dr. Stal also referred the Nearctic species, *Tingis oblonga* to the genus *Leptostyla*. In the *Biologia Centrali-Americana* (Rhynch., Vol. II, p. 11, 1897) Dr. G. C. Champion amplifies Stal's generic description of *Leptostyla* and describes seventeen new species from Central America.

The new species of *Leptostyla* described herein was taken about fifteen miles west of Clarksville, Tennessee, July 25th, 1915, by Mr. D. M. De Long while sweeping for Jassids. This pretty little species is quite distinct from the only Nearctic congener, *L. oblonga* Say, and can be easily differentiated from it by the following key:

First segment of the antennæ about three and a half times as long as the second; costal area of the elytra without a broad fuscous fascia just before the middle.....*L. oblonga* Say

First segment of the antennæ twice as long as the second; costal area of the elytra with a rather broad, dark, fuscous, transverse fascia just before the middle.....*L. costofasciata* n. sp.

Leptostyla costofasciata spec. nov.

Somewhat closely allied to *L. constricta* Champion, but readily separated from it by the longer third segment of the antennæ, the trispinous head, the more heart-shaped anterior portion of the pronotum, and the much less constricted elytra. From the only described Nearctic congener, *L. oblonga* Say, it is quite distinct and can be readily separated from it by the characters given in the key, and, also, by the rather blunt and less prominent spines upon the anterior portion of the head.

Body moderately long and comparatively broad. Head short, with three rather blunt, porrect and slightly upwardly directed spines—the two smaller slightly converging spines situated just above the antennæ (one on the inner side of each); the larger, frontal spine is just above the other two; it extends a little farther forward and is slightly curved downward. Eyes rather prominent, strongly faceted; the facets giving them a morular appearance. Antennæ slender, about one-half the length of the body; first segment swollen, twice as long as the

second; second segment incrassated, very short; third segment quite long, slender, slightly more than three times as long as the fourth; fourth segment fusiform, pilose. Rostral groove rather wide, uninterrupted; rostrum almost reaching the meso-metasternal suture. Pronotum narrowed anteriorly, with the membranous margins moderately wide, recurved, converging anteriorly, with two rows of areolæ; hood oval, short, considerably raised, with eight areolæ on each side; the three longitudinal carinæ raised and when viewed from the side, composed of a single row of areolæ (middle carinæ more strongly raised than the other two), intermediate spaces between coarsely and quite

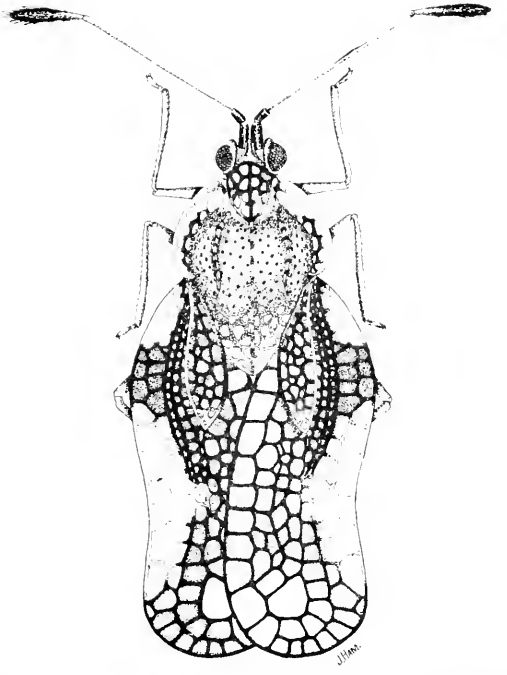

Fig. 1. Leptostyla costofasciata n. sp. (From camera lucida drawing of type by J. I. Hambleton.)

regularly punctured. Elytra rather long, slightly constricted about the middle, rounded at the tip, and extending far beyond the apex of the abdomen; costal area moderately wide, rather coarsely reticulated, with two rows of areolæ; subcostal area rather closely reticulated; discoidal area not reaching the middle of the elytra, more coarsely reticulated than the subcostal area; sutural area rather coarsely and unevenly reticulated, with two large areolæ near the tip. Wings not longer than the abdomen.

Color: First and fourth (except small basal portion) segments of antennæ, nervures of hood testaceous. Third and basal portion of fourth segment of antennæ and legs (tips of tarsi fuscous) yellowish.

Eyes and central portion of pronotum black. Outer membranous margins of the pronotum (except nervures of four or five areolæ near humeral angles), apex of pronotum, areolæ of hood and longitudinal carinæ white. Elytra with a rather broad, transverse, dark-fuscous fascia just before the middle; apex fuscous with whitish areolæ; costal area white, except fascia. Nervures of subcostal, discoidal, and sutural areas fuscous; the areolæ whitish.

Length 2.2 mm.; width 1.1 mm.

Described from three specimens taken at Clarksville, Tennessee.

Leptostyla oblonga Say.

Journ. Acad. Sci. Phil., Vol. IV, p. 325, 1825; Compl. Writ., Vol. II, p. 248, 1859 (Tingis).

This species is a little larger than the one described herein. It was described from specimens taken in Missouri. We have specimens from Arkansas (Osborn) and Washington, D. C. (Heidemann). The head has three elongate, acute spines upon the anterior portion and the costal area of the elytra is without a fuscous fascia.

Ohio State University.

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THE ORDOVICIAN-SILURIAN BOUNDARY.

W. H. SHIDELER.

Of late there has been an increasing disagreement as to just where the Ordovician-Silurian division should be drawn, and there has developed a strong movement toward shifting the division plane from its old and commonly accepted position at the Richmond-Albion (Upper Medina-Brassfield or "Ohio Clinton") break, down to the Maysville-Richmond break, thus incorporating the whole of the Richmond into the Silurian.

The shift in boundary is proposed* primarily for the following reasons, to express them briefly:

1. Only about 5% of the Maysville species are common to the Richmond, and these are nearly all generalized and long-lived types, while the Richmond introduces twenty new generic and four new family types; while all of the Bryozoa, Echinodermata, and most of the corals, trilobites and brachiopods are strikingly different.

2. The Ordovician relationships of the Richmond are neutralized by an equally strong Silurian tendency when compared with the Silurian.

*E. O. Ulrich. The Ordovician-Silurian Boundary. Etude faite a la XII. Session du Congres geologique international, reproduite du Compte-Rendu.

3. The Richmond-Albion break is regarded as impracticable for the separation of major time units, because there is no break there in the Anticosti series, and the break between the Lower Medina (Queenstown-Juniata—Richmond) and the Upper Medina (Albion—Brassfield or "Ohio Clinton") is frequently obscure.

4. The later Maysville seas were notably restricted, and at the close of the Maysville were drained away. The Arnheim shale (earliest Richmond†) was deposited over the gently warped surface of the interior, and the break is shown in overlap irregularities in sequence and thickness of deposits.

This break is correlated with larger and more distinct breaks in the Appalachian and other regions.

These points will be briefly discussed in order. However, it may be said here that the writer holds that in so far as crustal warpings and their consequent changes in land and sea relations are concerned, they are best reflected in the faunal changes which take place. The less local and more wide-spread the movement the greater the effect upon the life of the time. It is held that as a general proposition slight oscillations have but little repressive effect upon the forms of a given area, and but few new forms are introduced, while broad movements are likely to result in decided repressions on the one hand, and radical innovations on the other, and actual physical records of diastrophism might well be lost, obscured or inaccessible, and yet be reflected in a very positive and far-reaching way upon the life of the times.

1. In comparing the life of the Maysville with that of the Richmond, faunal lists have been based upon the recently published Bibliographic Index of American Ordovician and Silurian Fossils.* This has been modified by data collected by the writer and by Prof. S. R. Williams during seven seasons' systematic field work in the disputed strata. The lists include fossils from the Maysville of the Cincinnati dome, of New York and of Canada, and Richmond fossils from the Cincinnati region, the upper Mississippi Valley, and from the Fernvale

† In ascending order the subdivisions of the Richmond are commonly given as Arnheim, Waynesville, Liberty, Whitewater, Elkhorn, and Belfast. The Saluda is the western shallow-water equivalent of the upper half of the Whitewater and all of the Elkhorn.

* R. S. Bassler, Bull. 92, U. S. Nat. Mus., 1915.

of Illinois, Tennessee, Missouri, Arkansas and Oklahoma. The reasons for excluding the Anticosti series will be given later.

In these lists all forms of problematic origin, doubtful range and uncertain relationships have been excluded.

Of the 413 Maysville species, 58, or about 14%, lived on into the Richmond. Nor are all species of generalized types and long range, but we have among them such highly specialized cystoids as Streptaster vorticellata, Agelacrinus cincinnatiensis and Cyclocystoides magnus, while Bassler lists the starfish Hudsonaster incomptus and Mesopalaeaster shafferi. Heterocrinus juvenis and Iocrinus subcrassus represent the crinoids. Eleven species of Bryozoa are common, ten of Brachiopoda, six Pelecypods, ten Gastropods, four Ostracods, etc., etc.

Of the 217 Richmond genera, 116 are common to the Maysville. Of the 101 which are not, 68 occur below the Maysville, leaving 33 genera which are really new. And these introduce five new families, the Fenestellidæ, Rhopalonariidæ, Batocriniidæ, Halysitidæ and Loxonematidæ.

2. But contrast with this the fact that the Upper Medina (Albion) and Clinton give 255 genera, only 82 of which have been found in the Richmond, and of these 68 are long-ranging groups, which came up from Pre-Richmond times, usually Black River or Trenton.

Of the 173 genera not common to the Richmond, 40 also lived below the Richmond, leaving 133 as really new. And these 133 new genera introduce 35 new families, the suborders Larviformia and Sagenocrinoidea, the orders Madreporaria, Diploporita and Streptophiuriæ, and the subclass Hexacoralla. Should we consider the Upper Medina alone the proportion of new major groups would be still greater.

Compared with the above record the innovations of the Richmond seem almost lonesome, and the faunal break looms up still greater when we consider that of all the Richmond species, but one lone species, Halysites catenularia, occurs in the upper strata. But more of Halysites presently.

In comparing two faunas there is a difference of quality as well as of quantity, and both are of conspicuous value in comparing the Richmond and the Upper Medina-Clinton faunas.

To make a direct comparison between these two groups of faunas and see just how much the Ordovician relations of the Richmond are neutralized by the Silurian tendencies, 14% of the Maysville species are common to the Richmond, and but one Richmond species goes on up into the Upper Medina or Clinton.

While 68% of the Maysville genera pass the break into the Richmond, less than 4% of the Richmond genera pass on into the Upper Medina or Clinton. Or, if we add 16 Richmond genera that do not reappear until the Niagara, we still get less than 5% to compare with the 68% of Maysville genera passing into the Richmond.

The differences between faunas are shown not only in the introduction of new types, but also in the disappearance of old ones. Making new comparisons on that basis, 54 Maysville genera are absent from the Richmond, though 15 of these reappear later, leaving 39 which, so far as the strata have afforded us any knowledge, became extinct at the close of the Maysville. This would be very nearly 23%, and it includes three major groups, the families Pattersoniidæ, Anomalocrinidæ and Trinucleidæ.

In the case of the Richmond, we find 136 genera are absent from the Upper Medina-Clinton. But 16 of these reappear later, leaving 119, or over 54%, of the Richmond genera which became extinct, as compared with the 23% in the previous case. And here we have represented the extinction of 14 families, to compare with the 3 closing with the Maysville.

It is because the Anticosti strata are regarded as filling in the stratigraphic break between the Richmond and the Upper Medina, while their fossils fill in the faunal break and give us a faunal transition, that they were not considered in making up the faunal lists here considered.

Somewhere during Pre-Albion times there must have been evolving all of the species, genera, families, etc., which appear so suddenly and are so radically different from the Richmond forms. These groups, judged by the standards of present day evolutionists, must have required a very long time for their differentiation. It is not to be expected, then, that during all of this time at least a few of the hardier, wide-ranging forms should have migrated around their barriers into the Richmond sea? Broad diastrophic oscillations began in the

Maysville and culminated at the close of the Richmond, and the temporary lowering of barriers would be expected to let in a few forms. But it is significant that only a few new genera and only one species are common to the Richmond and the Upper Medina-Clinton, and the great invasion does not come in until after the Richmond–Upper Medina break. That break must have ended in the broader letting down of faunal barriers.

It may be said that H. catenularia is absent from the Richmond of the Cincinnati area, but it should occasion no surprise should it be found here.

3. When two series of strata are separated over broad areas by both a distinct physical break and a radical faunal difference, it should detract little if any from the value of that break as a division plane, should there somewhere be discovered a series of strata filling in the break.

For it is inconceivable that there should be erosion over the whole earth at once. Somewhere there must have been bodies of water, and in these must have accumulated the record of strata and of fossils which is represented elsewhere by the physical break. So, unless removed by subsequent denudation, there must exist somewhere a complete physical and faunal record of each break.

Therefore the filling in of such lost intervals is but to be expected, and it is not the presence of such transition strata which determines the value of the break, but it is the amount of sedimentation and the horizontal distribution of the transition strata, the amount of erosion and the degree of faunal break over broad areas, which determine the value.

4. If the Richmond–Upper Medina boundary, so distinct in Ohio, Indiana and Kentucky, be impracticable because the Richmond-Albion boundary is occasionally obscure, and if it thereby be degraded to a minor position, then the same thing certainly should apply to the Maysville-Richmond break, which may show a decided physical break in the Appalachians or elsewhere, but shows either the most obscure kind of a break in Ohio, Indiana and Kentucky, or else none at all.

It is to be expected in the shallows about the ocean margins that every little movement of the shore line will be strongly marked in the accumulating sediments. Here every little oscillation will produce a physical break, and the results of

a fair sized movement would be quite conspicuous. Yet even a fair-sized movement probably would show little or no effect upon the main sedimentation or upon the life of the sea as a whole.

Such appears to be the case with the Maysville-Richmond break. We should naturally expect to find breaks about the shores of the interior sea of this time, and we do get them in New York, Pennsylvania, Tennessee, etc., but over the broad interior, there is but scanty and obscure evidence of such a break.

It is not intended to deny the presence of such a break, but this break is held to have been the result of a broad though feebly developed and fleeting upwarping, not to be compared either physically or faunally in its results with later movements.

If the Arnheim be taken as the basal member of the Richmond, then it cannot be said that there is any definite physical break between the Maysville and the Richmond, at least in Ohio, Indiana and Kentucky.

The evidence as shown in overlap irregularities in sequence and thickness of deposits is inconsistent and obscure at the best. And the evidence is much less distinct than it is in the case of the breaks at the top of the Arnheim, at the base of the Whitewater (Gyroceras baeri zone, where in Adams County and elsewhere there is a veritable basal conglomerate), at the base of the Saluda, within the Saluda and at the top of the Saluda-Elkhorn.

To summarize the evidence here presented, the Maysville-Richmond break is found to be inconvenient and inadequate physically. Regardless of the evidence of physical breaks, the close relationships of the two faunas speak for itself.

And the radical difference between the faunas of the Richmond and the Upper Medina-Clinton indicates a greater period of disturbance and a greater letting down of barriers than in the case of the close of the Maysville.

To make a few more comparisons, 58 times as many Maysville as Richmond species pass on up; 4 times as many new genera and 7 times as many new families are introduced during the Upper Medina-Clinton as are introduced during the Richmond; nearly 5 times as many families close with the Richmond as close with Maysville; 3 times as many genera failed to pass

the Richmond-Upper Medina break as failed to pass the Maysville-Richmond break.

Retaining, then, the Ordovician-Silurian boundary at its old and generally accepted position between the Richmond and the Upper Medina, a slight refinement may be made in the drawing of the boundary in Ohio.

The Richmond has been considered as ending with the Belfast* beds, a series of strata developed in Ohio along the east side of the Cincinnati dome. They are generally barren of fossils, and chiefly on the basis of rather common annelid remains have been classed as Ordovician, despite the finding of Halysites catenularia and Orthis flabellites in them. But during the past season there have been added to these Dalmanella elegantula and var. parva, Rhynochonella janea and Hormotoma sublata, all found near Lawshe and near West Union, Adams County, Ohio.

Disregarding the annelid remains, which cannot be used in correlating anything, the total fauna of the Belfast is Brassfield (Upper Medina) in its affinities.

The Ordovician-Silurian boundary of Ohio, Indiana, and Kentucky should be drawn, then, at the top of the next underlying beds, the Elkhorn and its equivalents.

* Foerste, Jour. Cin. Soc. Nat. Hist., Vol. XVIII, Feb., 1896, pp. 161–199.

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THE EPIBRANCHIAL PLACODES OF SQUALUS ACANTHIAS.

(Fifty-two Figures and Two Tables.)

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The study of the epibranchial placodes of Squalus Acanthias was undertaken with a view to determining whether this type displays the characteristics with regard to contribution of cells to the visceral ganglia of the gill region by the corresponding placodes, which were described by Landacre ('10) in the catfish and ('12) Lepidosteus osseus.

In the catfish, this author described a contribution en masse, of placodal cells to Gang. VII, IX and X, by the corresponding placodes and concluded that the cells from these sources gave rise to gustatory or special visceral fibers.

In Lepidosteus, it was shown that the method of contribution begins by active proliferation of cells of the ectoderm, thus forming the placode. This process is followed by a contact between the ganglia and the placodes, due to a mesial migration resulting in the fusion of the placodal cells with the general visceral components of VII, IX and X. In Rana, Landacre and McLellan ('12) were unable to distinguish a definite gustatory division in the ganglia of the 8 mm. larva probably on account of the more rapid development in this form; but these authors describe the behavior of the epibranchial placodes as similar to that observed in Lepidosteus and Ameiurus, and also describe well defined placodes in the stages earlier than the 8 mm. larva.

The material used consisted of a 20 mm. shark embryo cut into sections 10 microns thick, stained with Delafield's hematoxylin and counter-stained with Orange G. An 18 mm. embryo, subjected to the same technic was used for comparison. All drawings were made with a camera lucida in magnifications of 50x and 620x respectively, and reduced to one-third the original size in reproduction.

Owing to the difficulty of securing successive stages of Squalus at close intervals, this study is based upon a comparison of all the epibranchial placodes in one specimen. The placodes

appear in other forms, as do the branchial clefts, in serial order from anterior to posterior, and it seemed probable that the various stages in development of the placodes of the VII, IX and of the four divisions of the X nerve would present the same kind of evidence that could be secured by a study of one placode, such, for instance, as that of the IX nerve, through a series of embryos of successively older stages.

In determining the relation of a visceral ganglion to the ectoderm, it is necessary to distinguish carefully, the following ectodermal thickenings: (a) the lateral line placode; (b) the thickening of the ectoderm at the point where the entodermal, pharyngeal pocket joins the ectoderm; (c) the ectodermal thickening extending anterior and posterior to (b); (d) thickenings of the epithelium of the entodermal, pharyngeal pocket which, after the gill slits are open, are continuous with the corresponding ectodermal thickenings (b).

A comparison of the 20 mm. and 18 mm. stages indicates that, of the ganglia in question, the VII undergoes the earliest development, hence, in the later stages, presents a more highly developed condition, and here, the placode is very marked and easily distinguishable from the thickenings associated with the gill clefts.

The placodes are characterized by a thickening of the ectoderm, by irregular arrangement of the cells, and by the presence of numerous mitotic figures, indicating rapid cell proliferation.

In the cases where actual cell contribution is observed, this activity takes place almost uniformly by migration of the cells from the placode toward the ganglion, followed by metamorphosis as follows; the cells on the mesial border of the migrating mass exhibit the characteristic darkly-staining, granular nuclei described by Landacre in Lepidosteus; in some cases, also, smaller size of the nuclei than those of the placodal cells that have not migrated, or of the cells of the visceral components, though this is by no means as constant as in Lepidosteus, and in fact, was not clearly marked in any case except Gang. IX.

Table I shows the ratio between the length of the area of contact between the placodes and the ganglia, and the total length of the ganglia themselves. It will be seen from this that the lengths of the areas of contact increase as we pass

posteriorly while the lengths of the ganglia diminish. Thus, there is, progressively, a greater extent of contact between the placodes and ganglia in proportion to the length of the ganglia. This is evidence of the greater maturity of the more anterior ganglia, which is in accord with the general law of antero-posterior differentiation.

TABLE I.

(Showing length of ganglia and contact area in 20 mm. embryo.)

Gang.	Length of Ganglia	Length of Contact Area	Ratio
VII	340 microns	10 microns	1–34.
IX	190 "	40 "	1–4.75
X_1	270 "	90 "	1–3.
X_2	130 "	90 "	1–1.46
X_3	150 "	120 "	1–1.25
X_4	210 "	160 "	1–1.4

Table II shows the length of the area of contact in the 18 mm. stage. The development has not progressed to the degree seen in the older stage and, consequently, there is less difference in the lengths of the contact areas in the younger stage than in the 20 mm. stage. The placodal contributions are proportionately much larger when compared to the size of the general visceral portions than in the older series. This is evidence that the total absence of the darkly-staining cells in the 22 mm. embryo, examined in connection with other work in progress in the department, may be interpreted as meaning, only, that these cells, in the latter case, have undergone complete metamorphosis and mersion with the general visceral cells so that they do not stain differently. This is also the probable explanation of the failure to distinguish them in Rana (Landacre and McLellan '12), since this form undergoes relatively more rapid development and the process was completed in the earliest stages studied.

TABLE II.

(Showing length of contact area in 18 mm. embryo.)

Gang.	Length of Contact Area
VII	180 microns
IX	160 "
X_1	100 "
X_2	90 "
X_3	80 "
X_4	100 "

Gang. VII.

Since this ganglion is the earliest to develop, there is, in the 20 mm. stage, a relatively small number of cells showing the characteristic distinguishing features of placodal cells. The ganglion is 340 microns long, but for only 10 microns or through one section, was there any actual contact with the ectoderm, while in the 18 mm. stage there is contact through 18 sections or 180 microns (Tables I and 11). In the 22 mm. stage, there is no contact and no cells which show the characteristic nuclei to a degree sufficient to permit of their being distinguished from the general visceral cells.

In the 20 mm. embryo, most of the ganglion lies anterior and dorso-mesial to the anterior extremity of the first true gill cleft, and the point of contact is just opposite the anterior end of the cleft. There are a number of mitotic figures in the placode and the migrating cell mass, showing that the processes of proliferation and metamorphosis are not yet completed.

The placode is an extensive thickening of the skin and at one point (Fig. 1 and 8), there seems to be a tendency to lamellation. The placode lies quite free and distinct from the thickening of the ectoderm which accompanies the opening of the gill cleft (c). Throughout most of its extent, the ganglion shows a well defined, encapsulated outline, which condition indicates maturity since it is not present to so great a degree in the more posterior ganglia.

The ventro-lateral lateralis component (Fig. 1 to 9, V. L. VII), constitutes the dorsal portion of the ganglionic mass and extends several sections posterior to the limits of the visceral portion.

Gang. IX.

This ganglion is 190 microns in length and the contact area occupies 40 microns of this length, giving a ratio of 1–4.75 between the total length and the length of the area of contact. The point of contact is approximately opposite the middle of the gill cleft and toward the posterior end of the ganglion. In the 18 mm. stage, the contact area is 160 microns long and so is not much smaller in extent than the contact area of VII in the same stage (Table II).

The placodal thickening of the ectoderm is not so marked as in VII, but the irregular arrangement of the cells, the presence of mitotic figures and the tendency to lamellation of the placodal mass (Fig. 14 and 15) are evidences of the integrity of the mass, which is quite distinct from the lateralis placode and, toward the posterior end of the ganglion, from the gill cleft thickenings also. The outline of the general visceral portion of the ganglion is maintained for several sections posterior to the point of contact (Fig. 10) with the placodal mass, and the boundary line between this and the placodal mass is quite distinct and intact at some points (Fig. 10, 11, 12 and 15).

In the mass of contributed cells, as well as in the placode, there are numerous mitotic figures and there is, in every section, a large group of undifferentiated cells (Fig. 11 to 15), lying near the ectoderm, except near the anterior extremity of the ganglion. Mesial to this mass is an area of cells with much smaller, dark, granular nuclei, representing a stage of incomplete metamorphosis (Fig. 10 to 16, S. V. VII). The boundary between this and the general visceral mass is quite abrupt and distinct in most sections, but in some there is evidence of fusion with the latter mass (Fig. 13). These facts are presented as evidences of the active state of proliferation and metamorphosis.

The process of contribution to the ganglion does not persist posterior to the point of disappearance of the general visceral portion, though the placode persists several sections posterior to both.

It will be seen from these conditions, that Gang. IX presents a much less mature condition than Gang. VII, which is to be expected from the evidences already presented (Tables I and II).

Gang. X.

The main mass of the ganglion does not come into contact with the ectoderm except at the extreme posterior extremity; instead, it gives off four branchial ganglionic masses which extend ventro-lateral something after the manner of the fingers of a hand, and come into contact with the ectoderm of the third, fourth, fifth and sixth gill bars respectively. The length of each branchial division is measured from the point of its complete separation from the main ganglionic mass.

The length of the first branchial ganglion of X, is 270 microns and the area of contact is 90 microns in length and situated toward the posterior end of the ganglion. This gives a ratio of 1–3 between the length of the contact area and the total ganglion length (Table I). In the 18 mm. stage, the length of the area of contact is 100 microns (Table II).

The oval outline of the ganglion, as seen anterior to the point of contact, persists posterior to the first section in which contact is seen (Fig. 22), but finally becomes indented by contact with the placodal mass so that the lateral curve is lost (Fig. 23 and 24), but the boundary between the general visceral and placodal components is quite distinct and persists throughout the entire length of the contact. The contact occurs toward the posterior end of the gill cleft and is directly mesial to the external aperture of the cleft. On account of its proximity to this structure, it is impossible to distinguish the placode from the other ectodermal thickenings associated with the gill clefts.

In Fig. 22, the cells with dark, granular nuclei lie in contact with the placode and there are no mitotic figures, showing that the processes of contribution and metamorphosis are slower in this region and so, more nearly complete toward the anterior end of the contact. This is true of all ganglia. In the more posterior sections (Fig. 23 and 24), there is evidence of more active proliferation, since there are large masses of undifferentiated cells to be seen, which have probably become detached en masse, lying near the ectoderm. The smaller size of the nuclei of the placodal cells is not so marked as in Gang. IX.

The second branchial ganglion of X presents a different arrangement from the first, in that the point of contact is with the entodermal evagination from the pharynx which enters into the formation of the gill cleft, at the anterior end; toward the posterior end, the contact is with the ectoderm at a point dorso-mesial to the external aperture of the cleft. The branchial ganglion is entirely free from the main ganglionic mass of X several sections anterior to the anterior end of the gill cleft.

The length of the ganglion is 130 microns and the length of the contact area is 90 microns, giving a ratio of 1–1.46 between the contact length and the total ganglion length. In the 18 mm. larva, the length of the contact area is 90 microns, also, though the length of the ganglion is not so great as in the older stage (Tables I and II).

The distinction between the placode and the gill cleft thickenings is difficult to determine, at least, in the more anterior sections, though the irregular arrangement of the cells of the ectoderm and the presence of a few mitotic figures are evidences of proliferation. In the first section in which contact is seen, the mass of contributed cells is quite large and persists posterior to the point of disappearance of the visceral portion, so that the placodal portion lies well toward the posterior end of the ganglion, most of which lies anterior to the middle of the gill cleft.

The oval outline of the visceral component persists after contact (Fig. 30) and the boundary between this and the placodal component is quite distinct, even posterior to the point at which the lateral curve of the visceral mass becomes indented by contact with the placodal mass (Fig. 31). In the more posterior sections (Fig. 32 and 33), there is fusion between the two components to such an extent that the boundary is not so distinct. There is evidence of rapid contribution in the presence of a large mass of undifferentiated cells near the ectoderm (Figs. 30, 31 and 32). The metamorphosing cells possess nuclei but slightly smaller in size than those of the other cells of the ganglion.

In the third branchial ganglion of X, also, the most anterior contact is with the entodermal gill pocket from the pharynx instead of with the ectoderm (Fig. 34, 35, 36 and 37). The length of the ganglion is 150 microns and that of the contact area, 120 microns, giving a ratio of 1–1.25 between the length of the area of contact and that of the total ganglion. In the 18 mm. larva, the length of the contact area is 80 microns, showing that the process of contribution has probably not progressed to so great a degree in the 20 mm. stage as it has in the VII and IX ganglia in the younger stage (Tables I and II).

In the more anterior regions, it is impossible to distinguish between the placode and the gill cleft thickenings but, in the more posterior regions, the distinction is quite clear (Fig. 39, 40 and 41). Proliferation and metamorphosis are evidently going on quite rapidly throughout the entire length of the contact and the placodal mass persists in considerable size to the posterior end of the ganglion. There is no appreciable difference in size between the nuclei of the metamorphosing cells and those of the neighboring cells but the dark stain and

the granular appearance are in evidence throughout. There is evidence of active proliferation in the placode, though metamorphosis is evidently not proceeding so rapidly, since the mass of metamorphosing cells is quite large in proportion to the size of the mass of undifferentiated cells. There is no distinct boundary line between the placodal and general visceral components, showing that fusion between the two is quite complete. The placodal mass does not persist to the posterior extremity of the ganglion but seems to occupy a position about the middle of this structure.

In the fourth epibranchial of division X, the form and position of the ganglionic mass are such as to make the contributed mass probably appear larger than it actually is. The length of the ganglion is 210 microns and that of the contact area is 180 microns, giving a ratio of 1–1.4 between the contact area and the total length (Table I). In the 18 mm. embryo, the length of the contact area is 100 microns. This is further evidence of a lesser degree of maturity in the more posterior ganglia.

The point of contact lies dorso-mesial to the middle of the external aperture of the gill cleft (Fig. 42 to 50). The placode is easily distinguishable from the other ectodermal thickenings throughout the entire length of the ganglion (Fig. 43, 44, 45, 47 and 48). The general visceral portion of the ganglion does not maintain its outline after contact with the mass of contributed cells and there is such complete fusion between the two masses that a definite boundary is not discernable except in Fig. 49. The presence of mitotic figures, the complete fusion between the general visceral and placodal masses and the large size of the latter, indicate very rapid proliferation, while the large size of the mass of incompletely metamorphosed cells as compared to the size of the mass of undifferentiated cells, indicates comparatively slow metamorphosis.

In Fig. 45 and 46 there may be seen a constriction in the mass of contributed cells which later results in complete separation between the ganglion and the placode (Fig. 47, 48, 49 and 50), leaving a large mass of cells attached to the placode. This mass, in some sections, shows a tendency to lamellation (Fig. 49 and 50). Posterior to the point of complete separation of the ganglion from the placode, the contributed mass is relatively much smaller than the general visceral portion.

There is another point of contact between the ectoderm and the main ganglion of X in the post-branchial groove where there is an appreciable thickening of the skin and a definite enlargement of the ganglion, also some evidence of contribution of ectodermal cells to the ganglion, but no separate epibranchial division.

Summary.

1. The epibranchial placodes of Squalus Acanthias arise as proliferations of the ectoderm about the middle and dorsal region of the corresponding branchial clefts.

2. Contribution of cells by the placodes to the visceral ganglia is by proliferation and mesial migration, the cells coming into contact with the caudal extremity of the corresponding ganglia.

3. With but two exceptions, the placodes are easily distinguishable from the other ectodermal thickenings in the same regions.

4. The placodal cells, in the course of migration, undergo a process of metamorphosis, during which the nuclei become darker and more finely granular, and in Gang. IX, smaller in size. In the older ganglia these migrating masses of placodal cells are completely fused with the general visceral masses and the cells of the two components are indistinguishable from each other.

5. There is a general similarity in behavior between the placodal cells in the shark and those of other forms in which this process has already been described.

6. The order of maturity of the epibranchial ganglia is from anterior to posterior, in progressive stages.

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EXPLANATION OF FIGURES.

All drawings were made from the posterior surfaces of 10 micron sections, with a camera lucida. Outline drawings were magnified 50x; high power drawings were magnified 620x. All figures were reduced to one-third the original size in reproducing. The sections are numbered serially from anterior to posterior, showing the relations of the sections used in the drawings.

KEY TO ABBREVIATIONS.

Aud.—Auditory vesicle.
Ec.—Ectoderm.
G. C.—Gill cleft.
G. V. VII—General visceral portion of the seventh ganglion.
G. V. IX—General visceral division of the ninth ganglion.
G. V. X_1, X_2, X_3, X_4—General visceral divisions of the first, second, third and fourth epibranchial ganglia of the tenth nerve.
G. X—The main ganglionic mass of the X nerve.
L. IX—Lateral line portion of Gang. IX.
L. X—Lateral line portion of Gang. X.
L. Pl.—Lateral line placode.
M.—Metencephalon.
Pl.—Placode.
S. V. VII—Special visceral portion of Gang. VII.
S. V. IX—Special visceral portion of Gang. IX.
S. V. X—Special visceral portion of the main ganglionic mass of the X nerve.
S. V. X_1, X_2, X_3, X_4—Special visceral divisions of the first, second, third and fourth epibranchial ganglia of the X nerve.
V.—Blood vessel.
V. L. VII—Ventral lateral line division of Gang. VII.

Plate XXIII.

Fig. 1. Sec. No. 216. Gang. VII, showing the placodal (Pl) thickening of the ectoderm at a point opposite the ganglion. The placodal contribution is small at this point and is characterized by the presence of cells with darkly staining nuclei; there are a number of mitotic figures, indicating active proliferation. Actual contact between the ganglion and the ectoderm is not present in this section.

Fig. 2. Sec. No. 222. G. VII. The distinguishable portion of the placodal contribution is much larger than in the preceding figure. There is a contact between the ganglion and the ectoderm, and the fact that the most external cells of the contributed mass do not show the characteristic dark nuclei, indicates active contribution of cells by the placode. The most recently contributed cells have not yet undergone the stage of metamorphosis seen in those that have migrated farther into the body of the ganglion.

Fig. 3. Sec. No. 224. G. VII. In this section, there is a reduction in the comparative size of the placodal component, absence of contact and a reduction in the number of mitotic figures, from the number in previous sections.

Fig. 4. Sec. No. 227. G. VII. There is still further reduction in the comparative size of the placodal component and a comparatively large area of undifferentiated cells on the external portion of the ganglion near the ectoderm.

Fig. 5. Sec. No. 231. G. VII. There is no evidence of actual cellular contact between the placode and the ganglion and, while still very near the placode, there is no evidence of recently contributed, undifferentiated cells on the lateral periphery of the ganglion.

Fig. 6. Sec. No. 233. G. VII. The dorsal portion of this section and the sections already described, constitute the lateral line component of VII (V. L. VII), the lower portion, the general visceral component; the latter, in this section, occupies an area of about the same extent as the placodal component, though this is reduced from the extent displayed in the previous section. There is still some active proliferation as evidenced by the presence of mitotic figures, not all of which are in focus at this level.

Fig. 7. Sec. No. 237. G. VII. The body of the entire ganglion is not so clearly defined at this point as in the more anterior and more mature portions. The placodal thickening is not greatly reduced and there is evidence of very active cell proliferation, though actual continuity of cellular elements is doubtful.

Fig. 8. Sec. No. 216. G. VII. An outline drawing of the same section as Fig. 1, showing the general relations of the area. The lateralis component is relatively smaller than the general visceral. The relation of the entire ganglion and the placode to the first gill cleft is clearly seen. There can be no doubt as to the independence of the placodal thickening from that situated at the opening of the gill cleft.

Fig. 9. Sec. No. 224. G. VII. An outline drawing of the same section as Fig. 3. The branchial cleft has deepened and the gill cleft thickening of the ectoderm is consequently carried farther away from the placodal thickening, which still maintains the form and size displayed in the intervening sections, as well as in those situated more posteriorly.

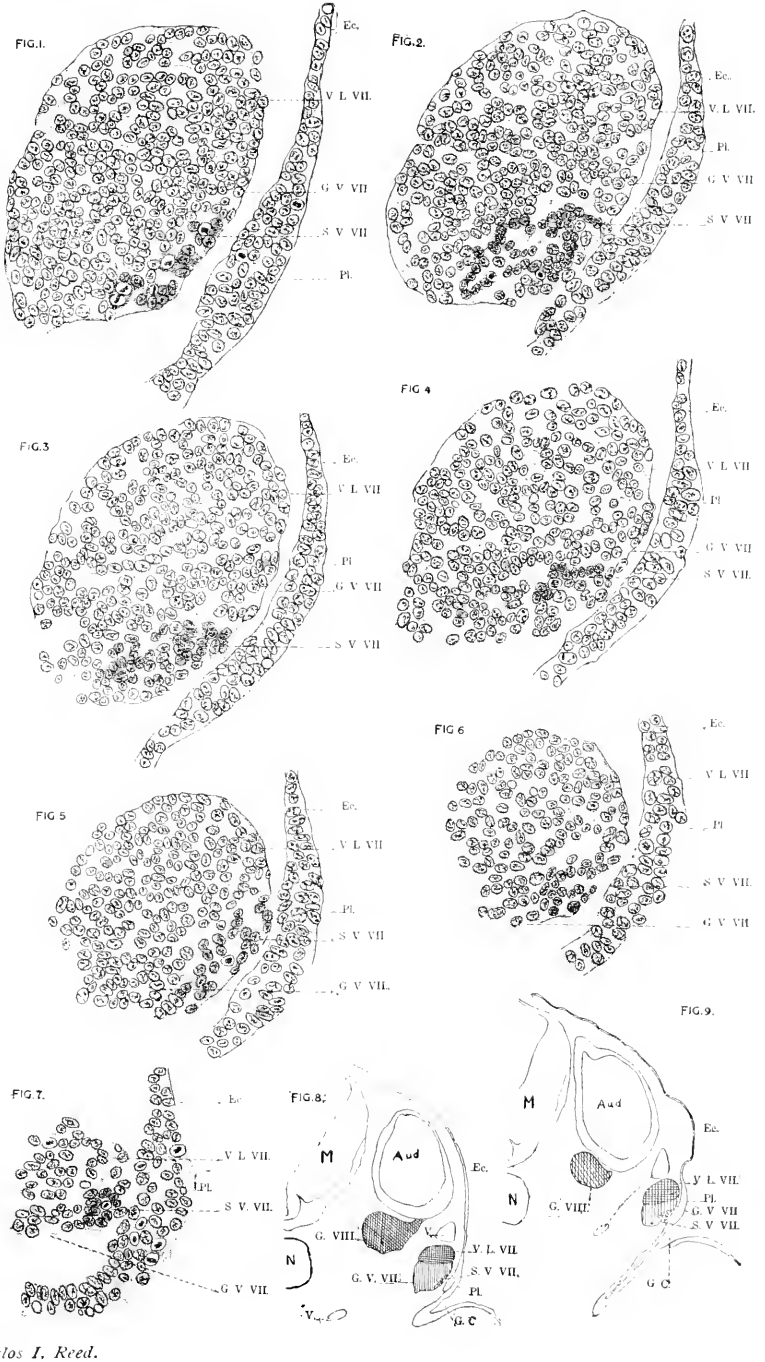

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Plate XXIV.

Fig. 10. Sec. No. 278. G. IX. A high power drawing of the most anterior section of Gang. IX in which there is contact with the ectoderm. The placodal thickening is quite marked and there is some evidence of active proliferation in the placodal area. The cells of the placodal component are smaller than those of the general visceral portion. There are a few cells near the ectoderm which have evidently been recently contributed from the placode and have not yet undergone metamorphosis.

Fig. 11. Sec. No. 280. G. IX. In this section, the smaller size of the nuclei of placodal cells is quite marked. The outline of the general visceral component is easily distinguishable throughout part of the extent of the contact with the placodal portion. Here again, may be seen a small mass of undifferentiated placodal cells lying near the ectoderm.

Fig. 12. Sec. No. 281. G. IX. In this section, the metamorphosing cells are completely surrounded by undifferentiated cells. The presence of mitotic figures indicates active proliferation.

Fig. 13. Sec. No. 282. G. IX. The extent of the contact with the ectoderm is greater than in the previous section. Proliferation must be going on more rapidly than metamorphosis, since the mass of undifferentiated cells near the ectoderm is larger and shows the cells massed more closely and tending to form lamellae.

Fig. 14. Sec. No. 284. G. IX. In this section, proliferation is very rapid as evidenced by the large mass of undifferentiated cells and the comparatively narrow field of placodal cells which have undergone metamorphosis. The marginal extent of contact is shorter than in the more anterior sections.

Fig. 15. Sec. No. 286. G. IX. The contributed portion of the ganglion is very large in proportion to the size of the general visceral ganglion. Several mitotic figures may be seen and there is a well marked margin of undifferentiated cells. The placodal thickening is dorso-lateral to the contact area which is still shorter in extent than in Fig. 14.

Fig. 16. Sec. No. 289. G. IX. The extensive placodal thickening still persists and active proliferation is still going on.

Fig. 17. Sec. No. 275. G. IX. This section shows the relation of the lateralis and visceral components anterior to the point of contact. It is, here, impossible to distinguish the placodal thickening from that accompanying the gill cleft opening, which lies ventral to it.

Fig. 18. Sec. No. 278. G. IX. An outline drawing of the same section as Fig. 10. The lateral line placode is very distinct from the epibranchial placode. The epibranchial placode, since the gill cleft is open, is easily distinguishable from the gill cleft thickenings of the ectoderm.

Fig. 19. Sec. No. 280. G. IX. An outline drawing of the same section as Fig. 11, showing the relation of the contributed mass to other structures.

Fig. 20. Sec. No. 287. G. IX. An outline drawing one section posterior to Fig. 15, showing the dorso-lateral point of contact.

Fig. 21. Sec. No. 296. G. IX. Showing the appearance of the lateralis component of Gang. X, the great thickness of the lateral line placode, and the relative size of the placodal and general visceral portions of Gang. IX.

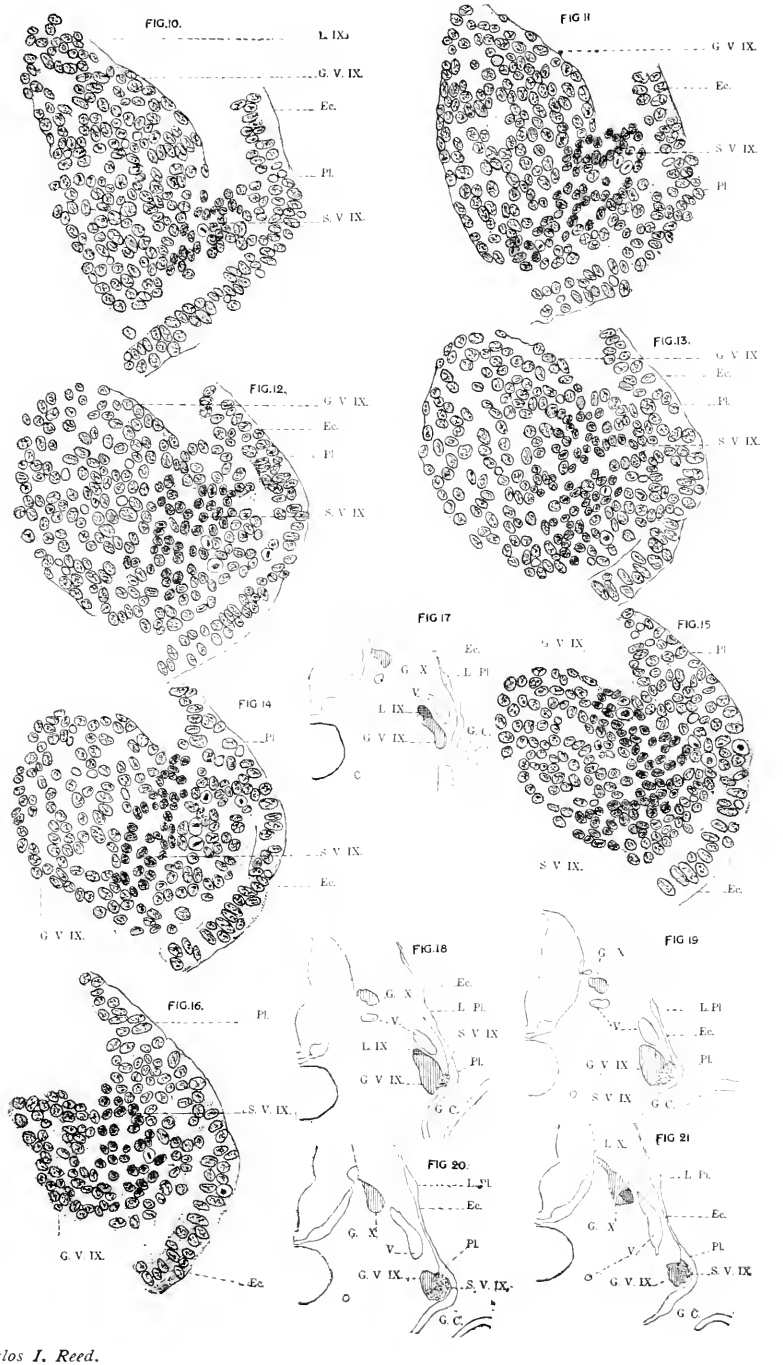

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Fig. 22. Sec. No. 320. G. X_1. Showing the contact point just mesial to the external opening of the gill cleft. There are no mitotic figures in the contributing area, but there may be seen a very definite zone of metamorphosing cells along the lateral border of the ganglion.

Fig. 23. Sec. No. 324. G. X_1. Two points of contact are seen and proliferation is going on quite rapidly, from the fact that there is a large mass of larger and more clearly stained cells between the two points of contact and external to the metamorphosing zone. The outline of the visceral portion of the ganglion is only fairly distinct.

Fig. 24. Sec. No. 326. G. X_1. The mass of metamorphosing cells is almost surrounded by undifferentiated cells. This, together with the presence of mitotic figures, indicates active proliferation from the placodal area.

Fig. 25. Sec. No. 323. G. X_1. An outline drawing of the section anterior to Fig. 23, showing the general topography and the relation of the ganglion to the gill cleft and the placode, the latter being indistinguishable from the ectodermal thickening accompanying the opening of the gill cleft.

Fig. 26. Sec. No. 345. G. X. This section shows the relation of the main ganglion to the ectoderm and the gill groove. The second epibranchial ganglion of X, G, V, X_2, is seen partly constricted off from the main ganglionic mass. A lateral line nerve is seen leading to the easily distinguished lateral line organ.

Fig. 27. Sec. No. 350. In this figure, the epibranchial ganglion is seen lying close to a thickening in the epithelial lining of the pharyngeal gill pouch. This thickening is continuous, in later sections, with the placodal thickening of the ectoderm, posterior to the point at which the gill cleft is entirely open.

Fig. 28. Sec. No. 351. The endothelial thickening persists and is nearer the external aperture of the gill cleft.

Fig. 29. Sec. No. 352. The endothelial thickening is more clearly defined than in the previous section.

Fig. 30. Sec. No. 352. G. X_2. A high power drawing of the same section as in the preceding figure, showing proliferation and a mass of cells with darkly stained nuclei which are not appreciably smaller than those of the cells of the general visceral ganglion. The oval outline of the general visceral portion and the boundary between this and the placodal portion are clearly seen.

Fig. 31. Sec. No. 353. G. X_2. Here the placodal thickening is clearly seen and there is much evidence of active proliferation.

Fig. 32. Sec. No. 357. G. X_2. The placodal thickening is still seen but the extent of contact with the ganglion is slight. The placodal cells constitute a much larger mass than the general visceral cells.

Fig. 33. Sec. No. 357. G. X_2. An outline drawing of the same section as shown in Fig. 32.

Fig. 34. Sec. No. 375. G. X_3. An outline drawing of a section anterior to the point of separation of the epibranchial ganglion from the main ganglionic mass of X; also anterior to the anterior extremity of the gill cleft, showing the lateralis component and a branch to the lateral line placode.

Fig. 35. Sec. No. 378. G. X_3. The outline of the general visceral component is fairly distinct and the mass of placodal cells relatively large; there is no contact with the ectoderm and it is impossible to distinguish the placode from the gill cleft thickenings.

Fig. 36. Sec. No. 380. G. X_3. The mass of contributed cells is very large but the placode is still indistinguishable from the gill cleft thickenings.

Fig. 37. Sec. No. 381. G. X_3. The general visceral portion of the ganglion is relatively small; there is evidence of active proliferation and a small area of contact but the extent of the placodal thickening is small.

Fig. 38. Sec. No. 383. G. X_3. The placodal thickening is quite marked and there is much evidence of active proliferation. The outline of the general visceral portion of the ganglion is quite distinct.

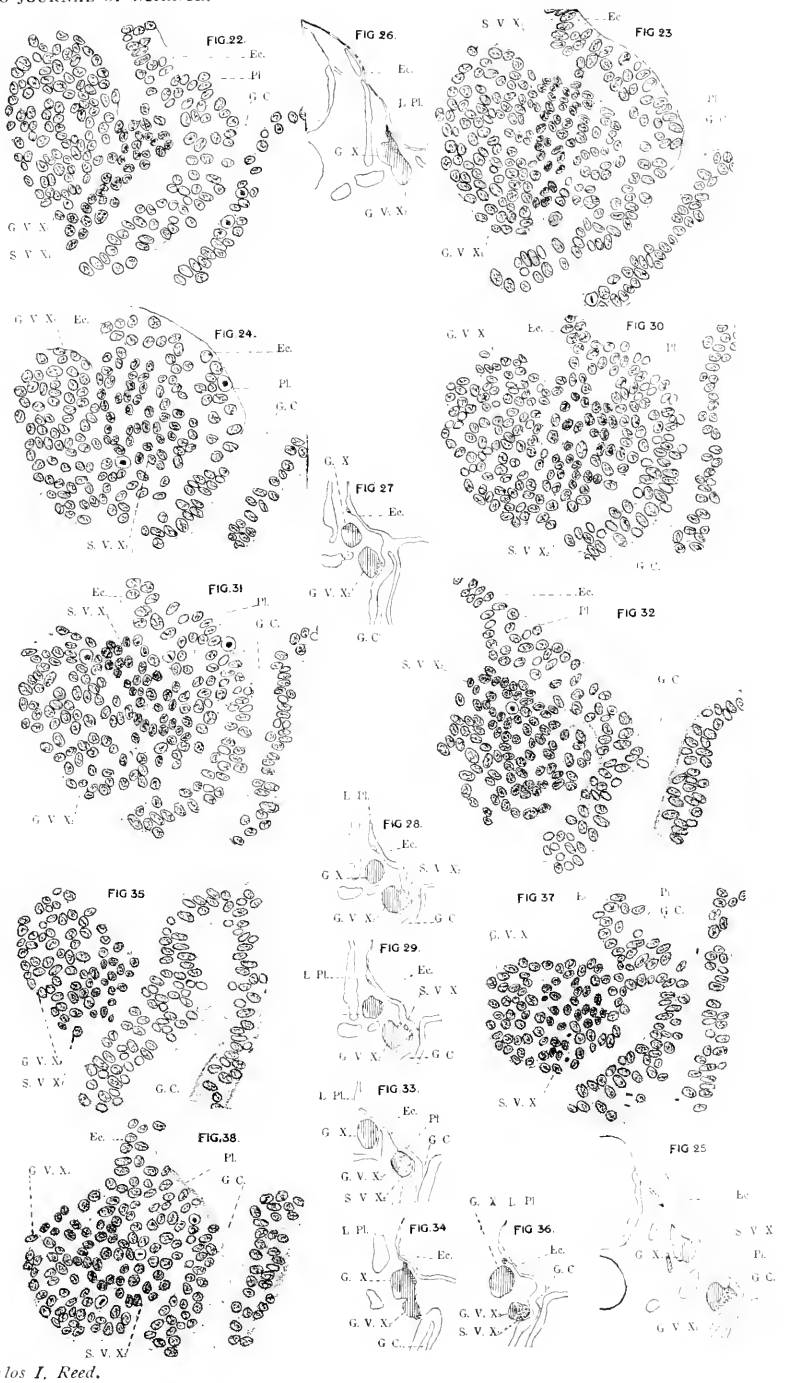

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Plate XXVI.

Fig. 39. Sec. No. 384. G. X_3. The mass of contributed cells is much larger in proportion to the size of the general visceral component, than in the preceding figure.

Fig. 40. Sec. No. 386. G. X_3. The placode is quite marked and there is active proliferation and an extensive contact area.

Fig. 41. No. 390. G. X_3. This section shows the placodal thickening persisting, even to the posterior extremity of the ganglion, where there is only a slight area of contact.

Fig. 42. Sec. No. 410. G. X_4. The apparently large size of the mass of contributed cells is probably exaggerated as a result of the peculiar form of the ganglion at this point. There is evidence of active proliferation but only a short area of contact.

Fig. 43. Sec. No. 410. G. X_4. An outline drawing of the same section as shown in Fig. 42, showing the relation of the placode to other structures. This magnification does not reveal the contact.

Fig. 44. Sec. No. 412. G. X_4. Showing the extensive contact and the large size of the mass of contributed cells.

Fig. 45. Sec. No. 413. G. X_4. The placode is quite distinct from the other ectodermal thickenings.

Fig. 46. Sec. No. 413. G. X_4. A high power drawing of the same section as shown in the preceding figure, showing evidence of active proliferation. The outline of the general visceral ganglion is fairly distinct.

Fig. 47. Sec. No. 415. G. X_4. Contact between the placode and the ganglion no longer exists but the placode is very large.

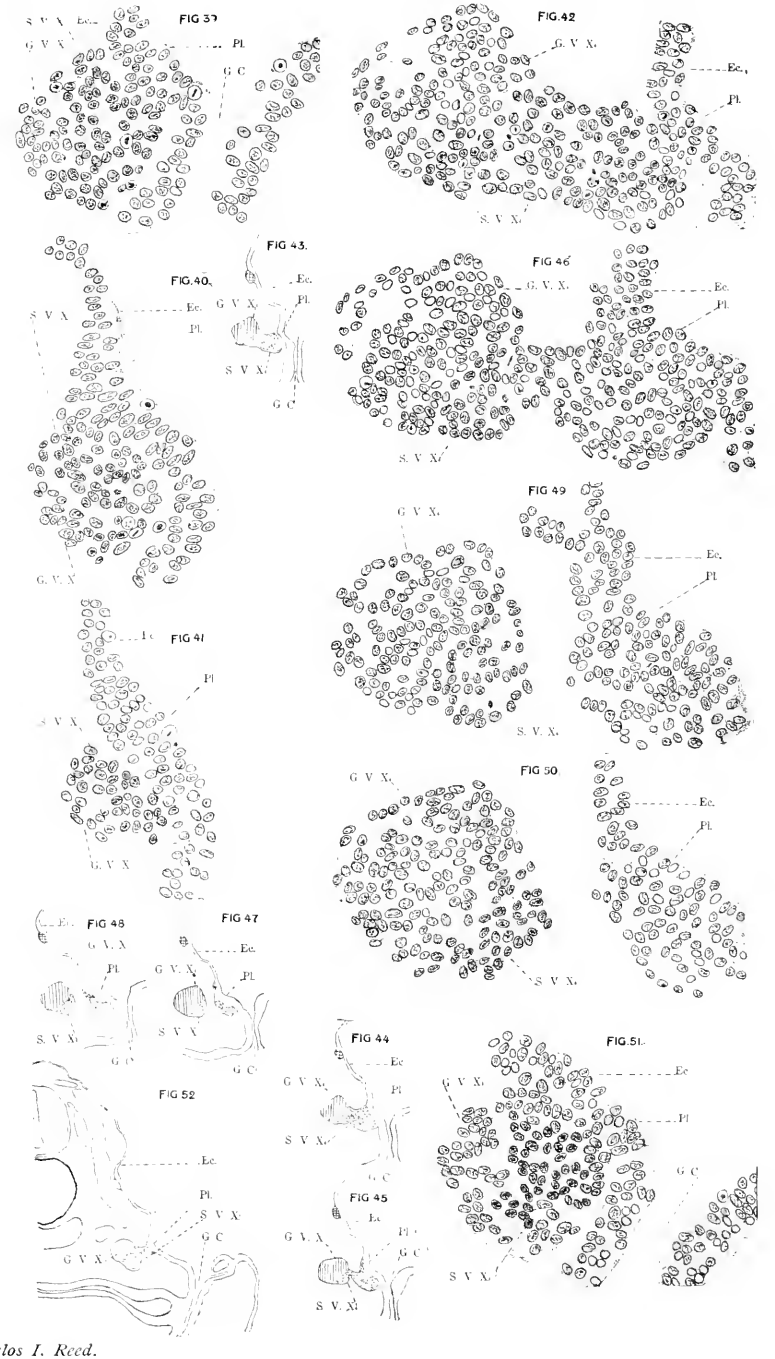
Fig. 48. Sec. No. 418. G. X_4. Showing partial detachment by lamellation, of the placodal mass from the ectoderm.

Fig. 49. Sec. No. 415. G. X_4. A high power drawing of the same section as shown in Fig. 47, showing a large mass of cells contributed by the placode but not yet metamorphosed. The outline of the general visceral component is fairly distinct and the nuclei of the placodal cells are slightly smaller than those of the general cells.

Fig. 50. Sec. No. 420. G. X_4. The placodal component is relatively small and a portion of the placodal mass is partially detached from the ectoderm by lamination.

Fig. 51. Sec. No. 329. G. X_1. A section of the first division of Gang. X, three sections posterior to that shown in Fig. 24.

Fig. 52. Sec. No. 428. G. X. Showing the general topography and the posterior extension of the main ganglionic mass of Gang. X, as it comes into contact with the ectoderm in the post-branchial groove.



Carlos I. Reed.

ADDITIONS TO THE JASSOIDEA OF MISSOURI.

J. L. Horsfall.

In Vol. XVI, No. 2, of this Journal, Gibson and Cogan published a Preliminary List of the Jassoidea of Missouri in which 98 species and varieties were recorded. The writer, while employed by the Missouri Fruit Experiment Station at Mountain Grove, Missouri, during the past two summers made a collection of 84 species of Jassoidea in that immediate region. Unless otherwise mentioned the specimens were collected by him. In this material are 29 species not listed in the above named paper. Thanks are due Professor Herbert Osborn of Ohio State University for verification and determination of six of the more doubtful species. The notes on the undetermined forms were furnished by him.

Idiocerus alternatus Fitch. One specimen taken July 3, sweeping low shrubs along a pasture creek.

Penthimia americana Fitch. Rare. One specimen dated July 5, in collection. Probably swept from Black Jack brush.

Xerophloea viridis Fabricius. Both the plain green and the dark form taken in September.

Gypona scarlatina Fitch. One specimen in traplight material from substation at Cuba, Missouri, May 26, 1914.

Platymetopius magdalensis Provancher. From Black Jack brush in July.

Deltocephalus areolatus Ball. In short grass in peach orchard, September. Taken sweeping in Winter Emmer by M. P. Somes, November 8, 1915.

Deltocephalus sp. "Near **stylatus** Ball but with different genitalia." Osborn. Common in weedy pastures July, August, September.

Athysanus striolus Fallen. One specimen September 5.

Driatura gammaroidea Van Duzee. Fairly common, July. Taken in timothy field in which there was an abundance of ragweed.

Driatura gammaroidea var. **flava** Osborn and Ball. Sometimes found with the preceding species.

Lonatura catalina Osborn and Ball. Found in grassy meadow August 22.

Acinopterus acuminatus Van Duzee. Specimen in the collection dated August 24. No food plant noted.

Eutettix cincta Osborn and Ball. Swept from undergrowth in shady woods Records for June, July, August, September.

Eutettix subaenea variety **querci** Gillette and Baker. Common on Black Jack brush.

Eutettix jucunda Uhler. Seldom taken.

Eutettix nigridorsum Ball. Occasionally on oak brush.

Eutettix johnsoni Van Duzee. Rare. One specimen Sept. 1.

Phlepsius excultus Uhler. Collected July 20, 1914.

Phlepsius altus Osborn and Ball. Everywhere common. Occurring throughout the summer on oak brush.

Phlepsius sp. Taken in August. "Near **truncatus** but not like my specimen under that name and not known to me." Osborn.

Scaphoideus unicolor Osborn. In sweeping shrubs along fence rows during July.

Thamnotettix fitchii Van Duzee. A specimen was secured September 5.

Thamnotettix kennicotti Uhler. Collected July 22. Not common.

Empoasca alboneura Gillette. Common in station collection with dates of July, August, September.

Dicraneura fieberi Low. One specimen sweeping wild grape vines July 3.

Alebra albostriella Fallen. Taken at porch light June 20.

Typhlocyba obliqua variety **dorsalis** Gillette. Collected from both wild and tame grapes, through July.

Typhlocyba obliqua variety **noevus** Gillette. From material at porch light June 20.

Typhlocyba comes variety near **vitifex**. "Differs from any I have in black spots on vertex." Osborn.

State University of Iowa.

STARCH IN APPLE TREES.

W. A. Price.

In the absence of reliable data and abundant literature upon the subject of starch storage and its changes throughout the year, I have undertaken experiments which I hope will shed further light upon the problem. The changes in the living tissues, the sap wood and particularly the bark, were found unexpectedly complicated. A few of the typical conditions may be given for which an explanation is not as yet attempted. The presence of starch in the non-living tissue, the heart wood, was studied in detail, believing the conditions found may have an important bearing in explaining the very ready decay of apple tree wood, in comparison with that of some other trees.

In case of the living tissue, sections about 20 mic. in thickness were made at intervals of ten days in dormant season, and four or five days during the growing season. The presence of starch was determined, in the usual way, by the iodin test. Each time, one-year old, or older, twigs were examined, both from the higher and lower portions of the crown of the tree; and beginning April 17th, the roots were examined.

This work was done at Ohio State University in the spring of 1914, under the general direction of Prof. Wendell Paddock, head of the Horticulture Department, and Mr. Forest B. H. Brown of the Botany Department.

The following typical conditions were found:

Date	Temperature		Age of Wood Yrs.	Pith	Xylem		Bark			
	Max. F.	Min. F.			Wood Par.	Ray	Ray	Bast Par.	Pri. Cortex	Phellogen
Jan. 9	42	34	1-9	+	+	+	0	0	0	0
Mar. 9	32	19	1-9	+	+	+	+	+	+	+
Mar. 19	26	20	1-10	+	+	+	+	0	+	+
April 24	77	51	1-10	+	+	+	+	+	+	+
May 14	63	41	1-8	0	0	0	0	0	+	+

+ = starch present. 0 = starch absent.

May 14, clear; March 9, partly cloudy; other dates, cloudy.

The conditions found on January 9th seemed typical for most of the winter months up to March. The remaining four sections show some of the many changes that were found from that time to the unfolding of the leaves. On March 9th occurred the first notable changes. As shown in the table, starch now appears in the bark, which does not agree with the results obtained by Gourley, Bulletin 9, New Hampshire Agricultural Experiment Station, for the ray tissue of the bark appears generally to show starch from this time (March 9) on during the period of observation (June 4).

Buds began swelling March 9 and opened on April 24, when the leaves were unfolding. While the buds were not greatly swollen, a great deal of sap was present. Also the grains of starch were generally corroded in the pith, and, to a much less extent, in the xylem throughout the upper portion of the crown. Twigs on the lower part of the crown indicated less activity, showing scarcely any corroding of starch grains. The first corrosion occurred in the one-year-old wood in the upper portion of the crown. About two days later, the same changes appeared in the lower portion of the crown. The starch began disappearing in the wood parenchyma, then the rays, and finally the pith, in the order named.

As before mentioned, changes appear first in the one-year-old twigs, then later in the older portions of the branch, as shown in the following table, made from a fifteen-year-old branch on May 1st:

Date	Age Yrs.	Pith	Xylem		Bark
			Ray	Wood Par.	
May 1...	1	+	0	0	0
May 1...	2	+	+	0	0
May 1...	3	+	+	0	0
May 1...	4	+	+	+	0
May 1...	5	+	+	+	0
May 1...	6	+	+	+	0
May 1...	7	+	+	+	+
May 1...	8	+	+	+	+

Besides showing the order in which the tissues are emptied of starch, it also shows how the process is delayed with the age of the stem. Beyond the eighth year no change has taken place by May 12th. Starch has nearly disappeared from all tissues above ground, except the heart wood.

Thus far, the storage of starch in living branch wood tissues has been considered. For the sake of comparison, sections from the trunk of a tree, with apparently non-living heart wood at the center, were now made. During the last week in January a tree showing 54 annual rings was cut at a height of one foot from the ground, and a series of starch tests made from outer bark to pith along both radii of the diameter. Very little starch was found in the bark. The sapwood just beneath the bark contained a considerable quantity distributed in the wood parenchyma and medullary rays, but mostly in the rays. The amount diminished inward from the bark gradually to the 12th year, then suddenly, from which point no starch was regularly found in the wood parenchyma, except at certain intervals to be described later. From the 23rd year, the wood had the dark brown heart wood color; here starch still occurred in the ray cells, but intermingled with empty cells. At certain intervals, 23rd, 37th and 51st annual rings, occurred places where the storage tissues, both rays and wood parenchyma, were densely filled with starch, particularly in the summer wood portion of the ring. Such starch accumulations in the heart wood may possibly be explained on the assumption of "excess storage"; i. e., years when conditions were favorable for the production and storage of starch, followed by a fruitless, or partly fruitless, season. Inasmuch as fruit production is probably one of the principal sources of starch consumption in the tree, one can readily see that a condition of abundant supply would exist with little provision for an outlet, and hence account for the accumulation of starch in the heartwood. The fact that more or less starch is stored in the annual rings throughout the heartwood, and is not used from year to year, but simply remains in the heart wood intact during the life of the tree, suggests a reason for the decay of the trunk and the inner parts of the larger limbs of the apple tree. It is well known that starch is one of the best foods for the nutrition of fungi, and when once the spores get access to the stored starch in the heartwood, it is only a short time until the spread of the fungus

reaches other portions, causing decay of the plant tissues, and very soon the body of the tree becomes a shell. The sap wood remains actively engaged in the functions necessary to the life of the tree, and fungi do not so easily get hold. This gives us the shell condition of the apple tree, which is so common in old orchards where wounds to the tree are neglected, and incidentally, artificial roadways made to the heartwood of the tree for the access of fungi.

In summary, it may be stated that, during the dormant period, starch reserve is stored in the living cells of the pith, wood parenchyma, and medullary rays of the apple. With approach of spring, starch is found in the tissues of the bark, appearing first in the phelloderm and collenchyma.

As the leaves begin to appear, starch begins to disappear from the various tissues in order as follows: bark, wood parenchyma, rays, pith. It is used first from the youngest wood of the branches in the top of the tree, later, from the lower portions of the tree, and finally from the roots.

A portion of the starch reserve may never be used in the growth of the tree, but remains behind to be included in the heartwood where it remains indefinitely and renders the wood susceptible to decay.

Purdue University.

A GENERAL SYSTEM OF FLORAL DIAGRAMS.

JOHN H. SCHAFFNER.

Diagramatic representations of flowers are of great convenience in assisting one's memory in respect to floral structions, especially when comparative and evolutionary studies are undertaken. Such diagrams have been in use for a long time and are found in most botanical text books and systematic works. However, as usually constructed they are rather vague and of various designs, which makes it difficult to employ them in any exact way. The writer has devised a system by which most of the essential structures of any flower may be represented by a single transverse diagram, which at the same time indicates in a general way the degree of advancement of the flower in the evolutionary series.

There are five general types of flowers which call for definite diagramatic representation, as follows:

1. Hypogynous flower, as in the lily.
2. Perigynous flower with a free hypanthium, as in the rose.
3. Perigynous flower with adnate hypanthium, as in the apple.
4. Epigynous flower without hypanthium, as in the honeysuckle.
5. Epigynous flower with hypanthium, as in the evening primrose.

The various signs used are as follows: carpel, a small circle (Fig. 1 a); vestigial carpel, the same in black (Fig. 1 b); axis of inflorescence, a circle with a dot in the center (Fig. 1 c); stamen, a pair of circles or figure eight without a line through the center if the anther has but two microsporangia or with a line through the center if it has four microsporangia (Fig. 1 d); vestigial stamen, the same in black (Fig. 1 e); united carpels, a large circle with radii to represent the partition walls, (Fig. 1 f); united carpels forming a unilocular ovulary, a similar circle with points on the inside to represent the place of union of two contiguous carpels (Fig. 1 g); sepal, a curved line, thickened in the middle (Fig. 1 h); petal, a curved line thickened in the middle and with a prominent point (Fig. 1 i). A necter pit or spur is represented as shown in Fig. 1 j. Bracts are

represented by curved lines of uniform thickness. The empty glumes and flowering glumes of grasses, on account of their importance, call for special treatment. The empty glumes are represented simply like a pair of bracts, but the lemma receives a narrow point at the middle projecting outward and the palet two such points, one on either side of the middle and some distance apart.

In representing spirals no attempt is made to show the "pitch," or irregularities. Only the average number of spirals with the number of parts in each, is shown, as in figures 2 and 3. Usually only one spiral line is drawn, as in Figure 3, which represents a cone with five spirals, with seven carpels in each spiral. Fig. 2 represents a cone with three spirals, each with nine carpels and all spiral lines represented.

Aside from representing the spiral curves, the diagrams can be made with a pair of compasses and ruler and finished in detail with a pen. Of course, many peculiarities may be added without detracting from the definiteness or clearness of the formal signs.

Figure 4 represents an ordinary hypogynous, actinomorphic, pentacyclic, trimerous flower with united carpels, like a Yucca or lily. If each petal sign were joined at its ends by a straight line to the sepal sign, the diagram would represent a flower like the lily-of-the-valley (Convallaria). In general, connecting lines mean union with or position on an organ.

Figure 5 represents a perigynous, zygomorphic pentacyclic flower with united sepals. The hypanthium is represented by a heavy dotted circle. Sepals, petals and stamens are shown situated upon this by the connecting lines. Nine of the stamen filaments are united, but one is free, showing plainly a diadelphous andrecium. The single free carpel is represented in the center and the slight adhesion of one pair of petals is shown by a dotted connecting line. In general, it is convenient for comparison to place all the diagrams with the odd sepal on top. The relation of the flower to the axis of inflorescence can then be shown by placing the proper sign above or below the diagram.

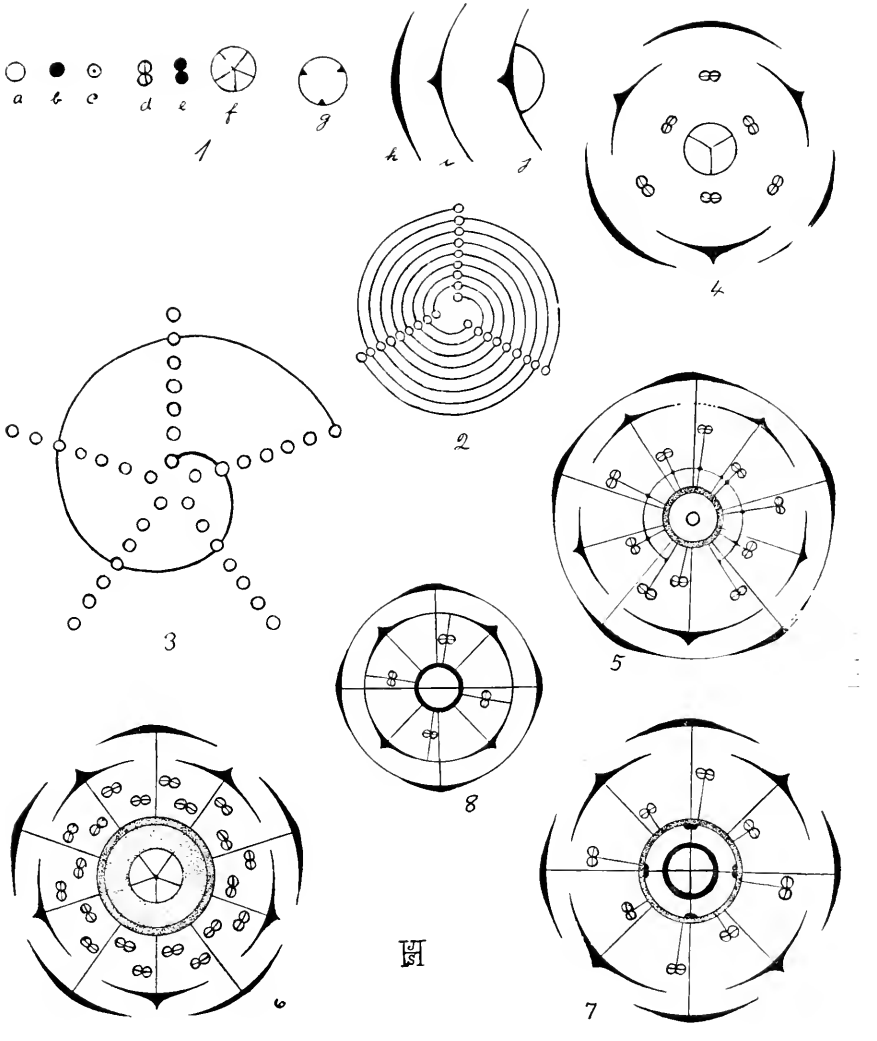
Figure 6 represents the diagram of an apple, in which the perigynous hypanthium is grown together with the ovulary. This is represented by filling in the space between the two with dots. The sepals and petals are on the hypanthium and are

therefore connected with it by lines. The stamens are also on the hypanthium and properly should also be connected with it by lines, but as they are sometimes very numerous, these lines may be omitted for convenience; since the position of the stamens between the perianth and the hypanthium necessarily implies that they are situated on the latter organ. The best rule to follow in this respect perhaps is that where the stamen are few in number and the lines can be drawn conveniently the connections should be made, but where they are very numerous, the connecting lines may be omitted, provided that they are shown with the parts of the perianth. The same procedure would be followed in epigynous types, either with or without hypanthium.

The epigynous type of flower with an epigynous hypanthium is represented in Figure 7. The representation of this type is the same in general as in the perigynous flower, but the hypanthium is connected with the ovulary wall by lines showing its superior position. The ovulary wall is shown with a heavy line in all epigynous types. This is merely to make the diagram more striking when compared with the hypogynous type and is not absolutely necessary since the epigyny is definitely shown by the connecting lines. Diagram seven represents Fuchsia, the four black oval spots inside of the hypanthium indicating four glands.

The epigynous flower without hypanthium is shown by figure 8, which represents Houstonia ciliolata. The calyx is composed of united sepals and the corolla of united petals. The stamens are distinct, but their filaments are united with the corolla. This is indicated by the line connecting the anther signs with the corolla sign. The lines connecting the anthers with the ovulary represent the epigyny of the stamens and the same is shown for the calyx and corolla. Extreme reductions and specialization like the pappus of the dandelion may be represented by a circle of dots.

In many cases it is possible to represent other structural details in connection with the usual floral organs, but nothing should be added that will obscure the real representation of the important and fundamental morphology of the flower. If properly and consistently constructed, such a series of flower diagrams will be found a great aid in any study of comparative morphology or evolutionary series.



John H. Schaffner.

EXPLANATION OF PLATE XXVII.

Fig. 1. The conventional signs used to represent the ordinary flower parts.
a. Carpel.
b. Vestigial carpel.
c. Axis of inflorescence.
d. Stamen.
e. Vestigial stamen.
f. United carpels, plurilocular ovulary.
g. Unilocular ovulary with three carpels.
h. Sepal.
i. Petal.
j. Petal with nectar cup.

Fig. 2. Diagram of carpellate cone of Tsuga canadensis, with three spirals.

Fig. 3. Diagram of carpellate cone of Sequoia washingtoniana, with five spirals, only one traced out.

Fig. 4. Diagram of hypogynous flower of Yucca filamentosa.

Fig. 5. Diagram of perigynous flower of Lathyrus odoratus.

Fig. 6. Diagram of perigynous flower of Malus malus, with adnate hypanthium.

Fig. 7. Diagram of epigynous flower of Fuchsia, with epigynous hypanthium.

Fig. 8. Diagram of epigynous flower of Houstonia ciliotata.

Ohio State University.

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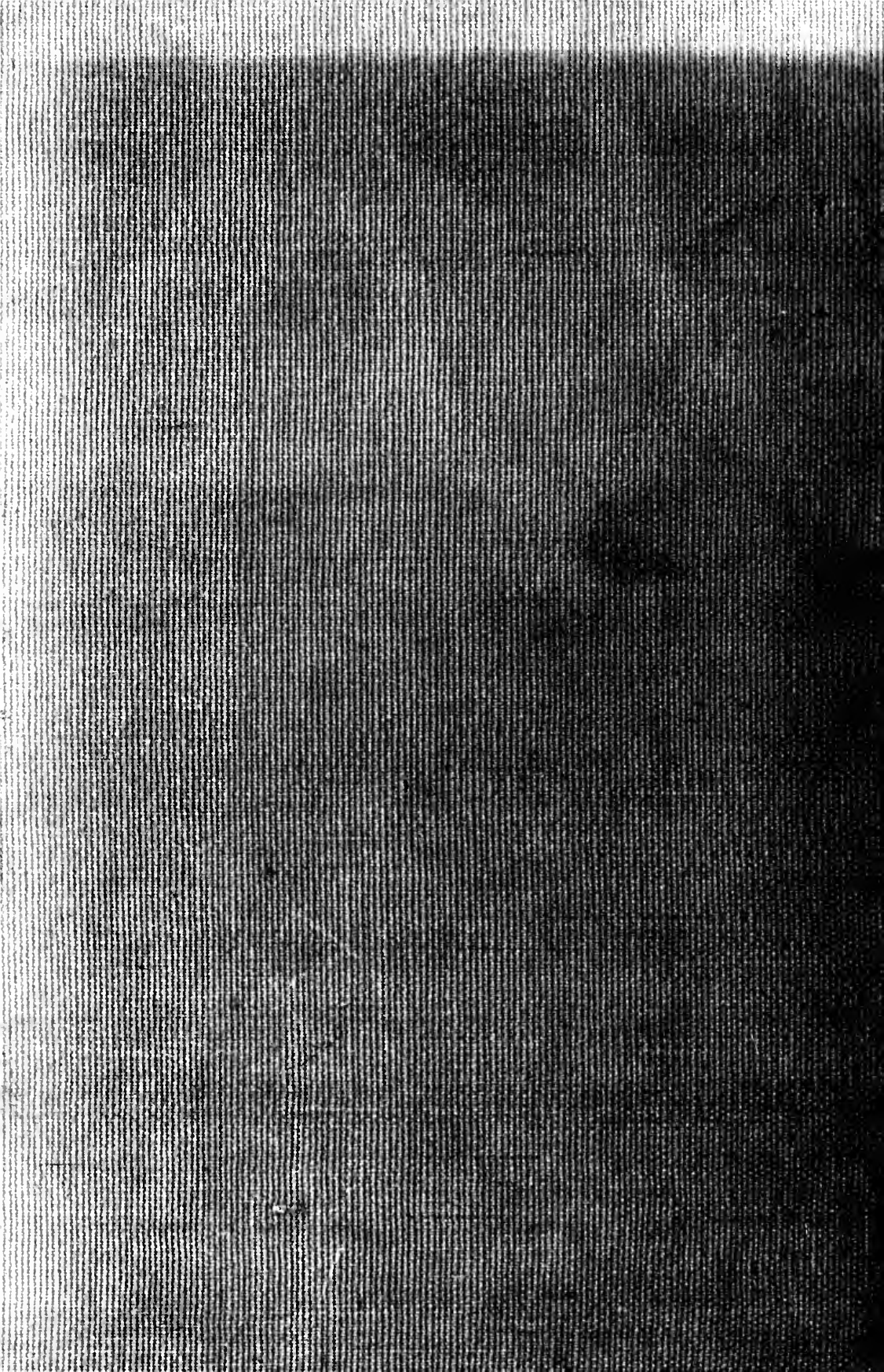
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